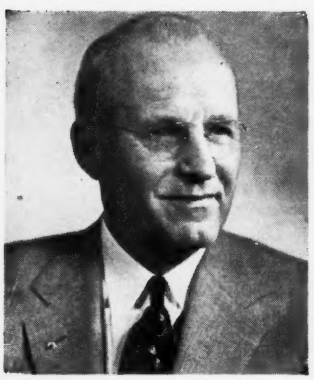
LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE



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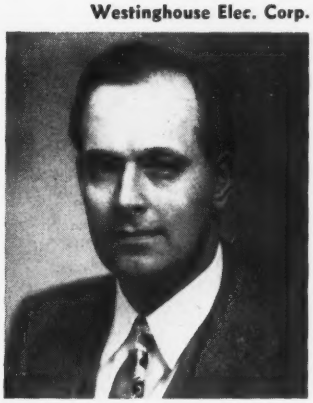
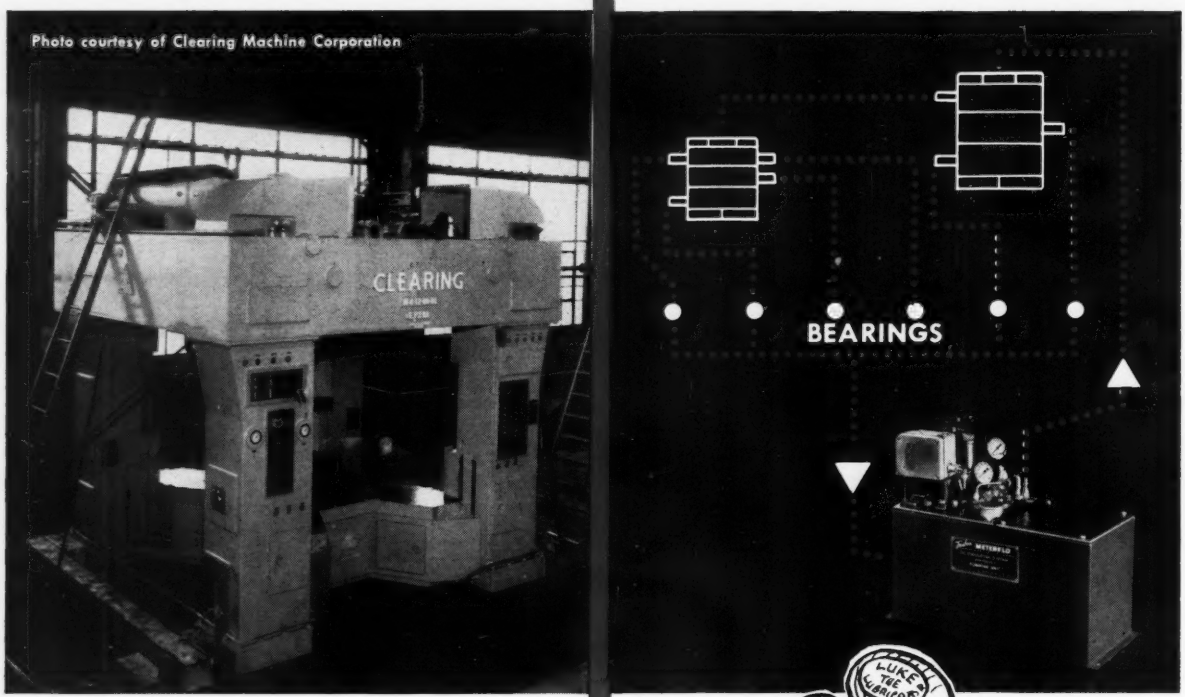


10th ASLE Annual Meeting & Exhibit Issue

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS



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ON 20-TON WELDING PRESS

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Membership in the American Society of Lubrication Engineers is in several grades as defined below. Assignment to grade is made by the Admissions Committee or Board of Directors on the basis of information submitted or supplied by references.

MEMBERS: Members shall be persons not less than 24 years of age who: (1) are engaged in research and instruction at technical schools, universities, and various publicly and privately supported institutions in the field of lubrication; or (2) have occupied recognized positions as lubrication engineers for a period of three or more (not necessarily consecutive) years prior to date of admission, involving the responsibility for or supervision of the development, selection, field use and application of lubricants as differentiated from other activities; or (3) are indirectly concerned with the field of lubrication, but possessing other qualifications of experience, knowledge, and accomplishment, and have manifested a particular interest in the purposes and welfare of the Society to the extent that their membership would be a valuable contribution to the successful functioning of its activities. Fee $12.50.

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For application blanks or further information, write:

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LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

Vol. 11, No. 2 March-April, 1955

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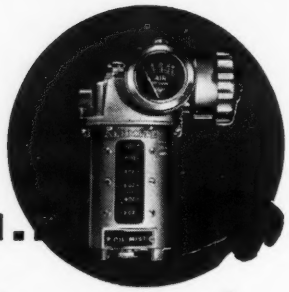

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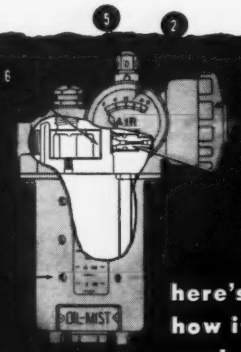
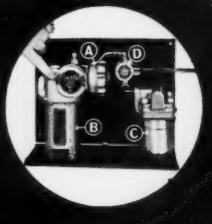
that protects any machine... any bearing surface!

ALEMITE OIL-MIST

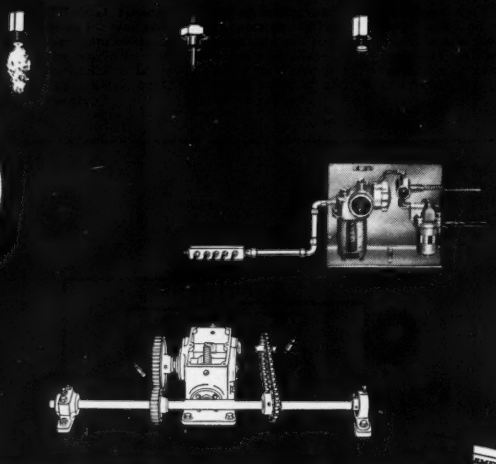


here's how it works!

This Oil-Mist lubricator atomizes oil into minute particles which are carried in the air stream through tubing to bearings. Compressed air enters through the air regulator (1) and air gauge (2). As the air passes the venturi (3) it draws oil from the reservoir (4). Oil flow is set by knob (5). The oil-air mixture is thrust against baffle (6), and only the tiniest, lighter-than-air particles are blown through the outlet (7) and through the delivery line to bearings.



Three types of bearing fittings



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B. J. Dempsey
New Departure Div.,
G.M.C.
(p. 91)

M. R. Fenske
Pennsylvania State
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(p. 101)

E. E. Klaus
Pennsylvania State
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F. J. Watson
Shell Development Co.
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CASE HISTORY NO. 34

REQUIRED

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ACTION

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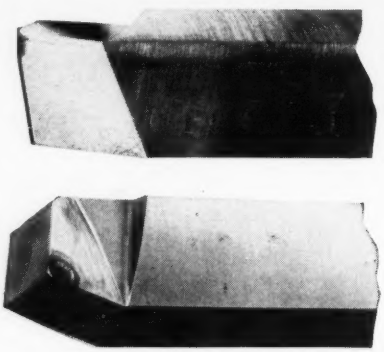

The cutting tool at top shows an abnormal front clearance caused by *excessive chemical activity* of cutting fluid. The lower cutting tool shows cratering, usually associated with poor finish, resulting from insufficient *chemical activity* of cutting fluid used.

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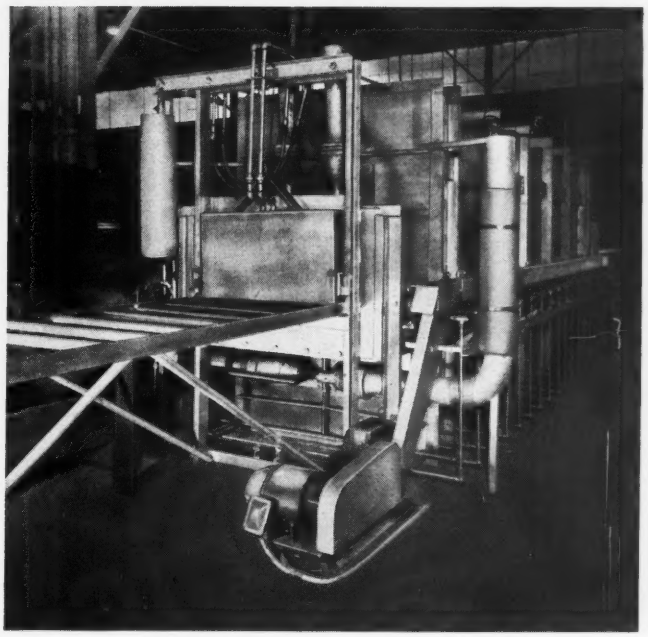

Here's how a Cleveland foundry proved the value of 'dag' *dry-film lubrication* in the operation of its continuous core-oven conveyor . . .

A 'dag' Colloidal Graphite dispersion was used in place of powdered graphite. The lubrication interval of conveyor chain and rollers was extended from *four* days to *sixty* days! In addition to tremendous lubricant and labor savings, conveyor wear has been notably reduced, carbon formation and flake-off eliminated.

This is typical of the extreme-temperature problems solved by 'dag' dispersions . . . problems with kiln cars and hot-strip mills . . . problems with *any* moving parts subjected to temperature extremes . . . problems where solvent action in degreasers or other situations destroys conventional lubricants.

You'll find a surprising number of ways to use 'dag' dispersions described in our free booklets. Write today for Bulletins No. 424-W7 and No. 435-W7.

Use 'dag' colloidal graphite to stretch maintenance dollars over 1400 percent!

Dispersions of molybdenum disulfide are available in various carriers. We are also equipped to do custom dispersing of solids in a wide variety of carriers.

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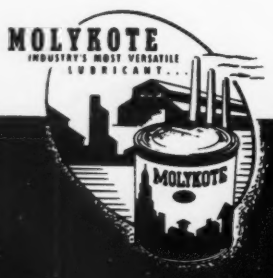

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U. S. GOVERNMENT RESEARCH REPORTS. Members of engineering societies, groups, and associations are urged to make more use of the growing stockpile of research reports released by the Federal Government through the Office of Technical Services (OTS) of the U. S. Department of Commerce.

The Government is conducting or sponsoring scientific and technical research at a current rate of $2 billion a year, mostly for defense purposes. By far the largest share represents applied research and development. This research generates a vast amount of non-confidential technical information that is available to businessmen and researchers who are interested in developing new production processes, in making technological improvements, and in avoiding duplication of research efforts. Even ideas for new products have been sparked by these reports.

Some 350 such reports are described each month in **U. S. Government Research Reports** (formerly "Bibliography of Technical Reports") which is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., or any of the U. S. Department of Commerce Field Offices, at $6 a year.

FIRE-RESISTANT TURBINE FLUIDS GAINING GROUND! Once again the utility industry and lubricant suppliers are wrestling with the intricacies of fire-resistant turbine fluids for bearing lubrication. Since steam temperatures are continuing to climb (planned 275,000 kw Westinghouse unit slated for Philadelphia Electric is being designed for 1200 F.) and there has been some degree of success with fire-resistant fluids in industrial hydraulics, the utility people are now pressing hard for a fluid possessing all the proved advantages of petroleum oil yet incorporating a greater degree of fire-resistance.

Right now several materials are under scrutiny. Closest contenders are the phosphate ester types and the hydrolubes. But both present problems that must be licked before they will find their way into an operating turbine-generator.

An excellent roundup article outlining where industry stands today, what products are available, and including a discussion of the problems yet to be solved, appears in the March issue of **POWER** starting on p. 75.

DEVELOPMENTS IN LUBE OILS & THEIR MANUFACTURE. There has been considerable development in motor oil compounding during recent years. The needs of the new high-output V-8 engines have accelerated this trend. In addition to increases in amounts of additives for detergency, oxidation resistance, and antiwear, it has been necessary to add anti-scuffing agents to overcome the heavier valve-train loads. There has also been a concurrent trend towards multipurpose oils covering several SAE viscosity grades with one oil, such as the range from SAE 10 to SAE 30. These oils are claimed to reduce friction through less viscosity drag at lower temperatures, and to decrease octane requirements through a decreased amount of engine deposits. Lube oils are thus being used to assist in meeting the increased octane requirements as well as to overcome the new lubrication problems of the high-output engines.

Processes for hydrogenating lube oil fractions to improve the finishing treatment have recently been installed. The Imperial Oil Company finish turbine and transformer oils by this method on a commercial unit at Sarnia and are building an additional hydrogenation unit at Edmonton as a substitute for conventional clay contacting for lube oil base stocks. A number of other installations are being considered for the United States. These processes all involve mild hydrogenation and are not being considered as a substitute for solvent extraction.

Shell Oil Company are using a new type of equipment for counter-current extraction. Called the "Rotating Disc Contractor," the device consists of a number of compartments formed by installation of stator rings in a tower, with a rotating disc centered in each compartment and supported by a rotating shaft. Normally, either the heavy or the light liquid may be dispersed. The device is now being operated in a number of locations on a commercial scale for the extraction of lubricating oil fractions with furfural. High efficiency and capacity, as well as simple construction and low-cost operation, are claimed.

PERSONNEL SERVICE FOR ASLE MEMBERS. On February 15, the American Society of Lubrication Engineers entered into an agreement with Engineering Societies Personnel Service, Inc., to provide an additional service to all ASLE members—a central clearing house for engineering employment. ESPS, Inc., a non-profit placement service, registers engineers seeking employment, and accepts employment opportunities. Experience of engineers, and job specifications, are classified according to comprehensive methods, and engineers so registering are exposed to any position for which they are qualified. Listings of Positions-and-Engineers Available are presented in each of the ESPS regional offices (located in Chicago, Detroit, New York City, and San Francisco), with appropriate listings appearing in the official publications of the following participating societies: American Institutes of Electrical, and Mining & Metallurgical Engineers (AIEE, AIME); American Societies of Civil, Lubrication, and Mechanical Engineers (ASCE, ASLE, ASME); Engineering Society of Detroit (ESD); Engineers Club of San Francisco (ECSF); Engineers Society of Milwaukee (ESM); Illinois Society of Professional Engineers (ISPE);

(Continued on p. 129)

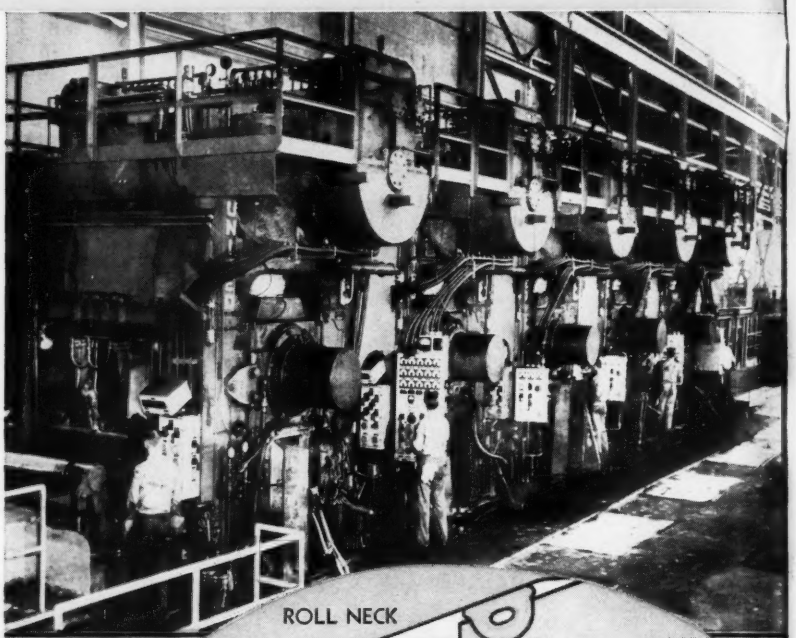
The MORGOIL FLINGER

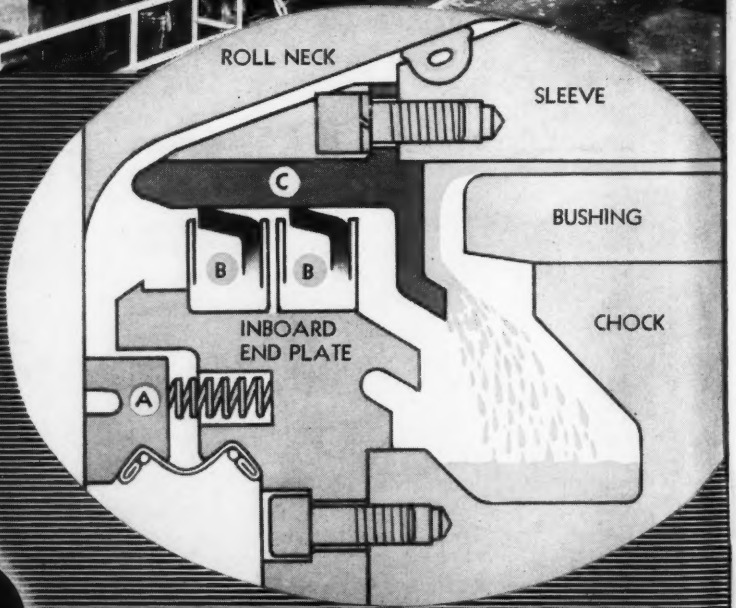
Stops oil loss on mills using rolling lubricant

The water seal assembly "A" and oil seals "B" of a modern MORGOIL serve only one purpose — **to keep rolling lubricant out of the bearings.**

The rotating sleeve extension and flinger "C" throws all of the oil from the bearing into the drain sump. No more oil loss through worn seals.

This five stand tandem four-high cold mill at Kaiser Steel Corp., Fontana, California rolls on modern MORGOILS equipped with sleeve extensions and flingers.





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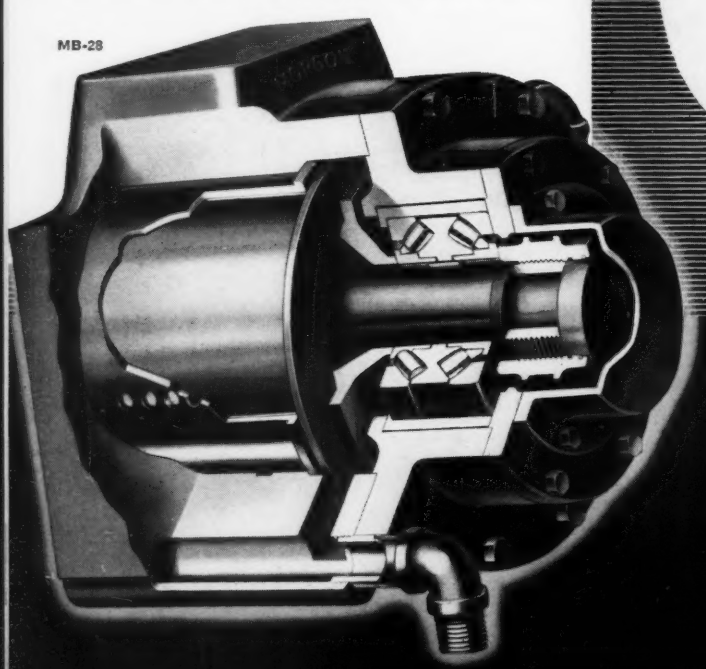

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No service is better than the men behind it. That's why Atlantic lubrication consultants, such as the man you see in the illustration, are experienced men with years of on-the-job knowledge of heavy industrial lubrication requirements.

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Behind their skills are 85 years of developing successful products for the use of our customers. Atlantic has pioneered in many historic firsts in the petroleum industry. To judge for yourself the value of Atlantic service, write, wire or phone the Atlantic office nearest you for full information on Atlantic lubricants for heavy industrial installation. The Atlantic Refining Company, Dept. L-4, 260 South Broad Street, Philadelphia 1, Pa.

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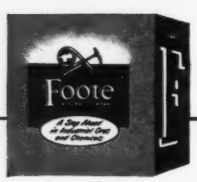
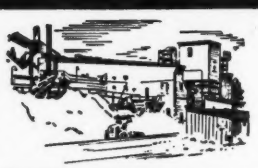
As a result of this ONE grease, inventory is greatly reduced and simplified lubrication procedures result in more efficient, economical operations.

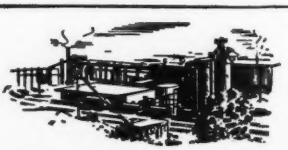
It will pay you to contact your grease supplier for information about lithium base, multi-purpose lubricating grease.



LITHIUM HYDROXIDE FOR INDUSTRY



Kings Mountain, N.C. . . . where Foote is mining large deposits of spodumene.



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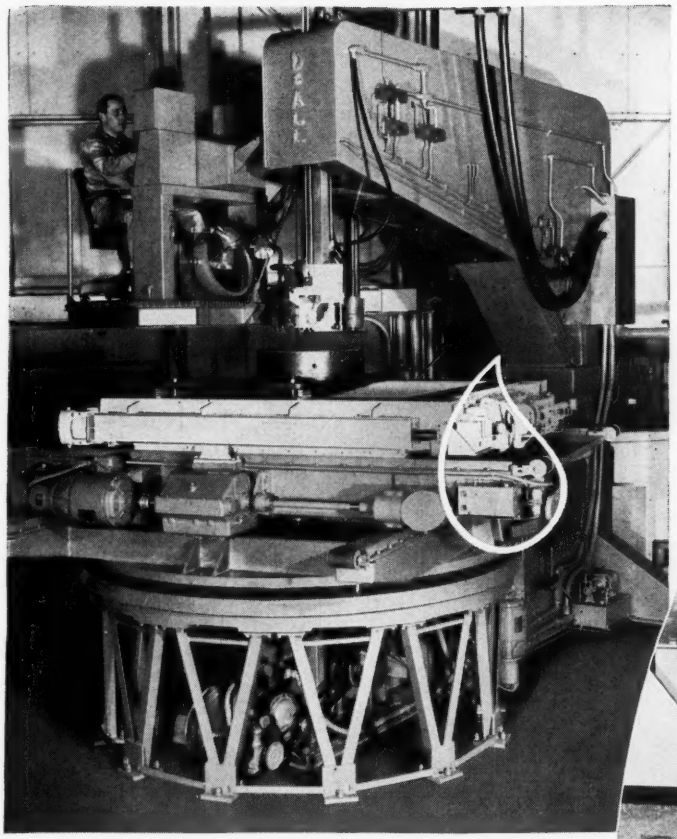

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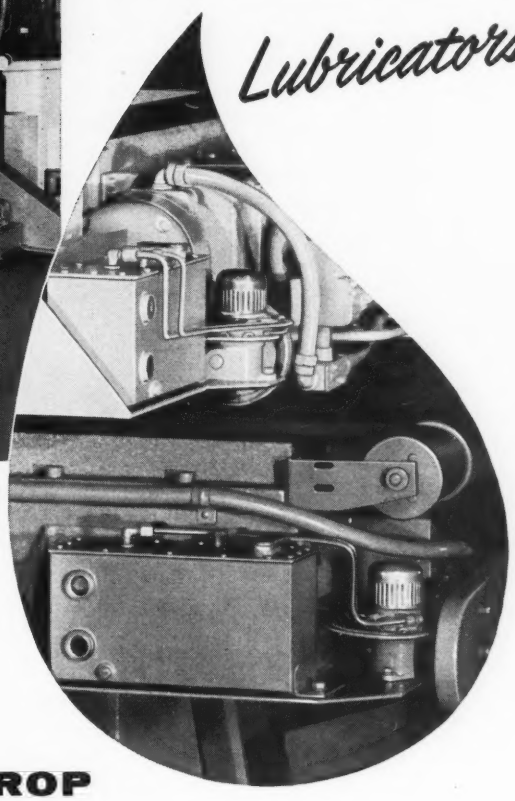
...MADISON-KIPP *Lubricators*



Two Madison-Kipp OL Lubricators installed on the world's largest band machine and die filer, manufactured by the DoALL Co., Des Plaines, Illinois...Operated by remote control, they machine 10-ton extrusion dies for the Air Force "Heavy Press Program."

Fresh Oil...

BY THE MEASURED DROP

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- **ELIMINATE REMACHINING COSTS**
- **USE LESS LUBRICANT**

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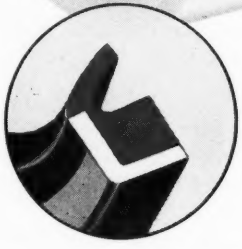
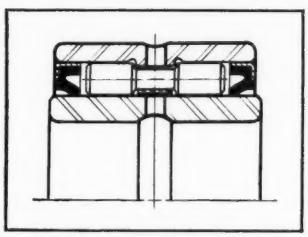


Above: McGill's new sealed Guiderol** bearing with two *built-in* springless KLOZURES, Model 71-A. *Left:* The Model 71-A has a narrow cross section consisting of a molded synthetic rubber sealing member securely bonded to and integral with a metal case.

In developing their new sealed Guiderol bearing, the designers of McGill Manufacturing Co., Inc., (Valparaiso, Ind.) required a dependable grease seal which could be built into the unit *without* increasing the overall bearing size.

Springless KLOZURE Model 71-A proved to be the answer! For here was a proven grease seal of narrow cross section specifically designed for limited space applications. Here, also, was a trouble-free seal which would keep out dust and retain the lubricant for the *life of the bearing.*

There's a service tested KLOZURE model for every bearing application. Let us show you how Garlock KLOZURES can solve your sealing problems. Just call the Garlock office nearest you or write for KLOZURE Catalog 10.



Two springless KLOZURES, lips turned in, on Guiderol bearing provide lifetime retention of lubricant. For relubricating at high pressures other sealing arrangements (with lips turned out; with one lip in and one out; and single seals) are available with these bearings.

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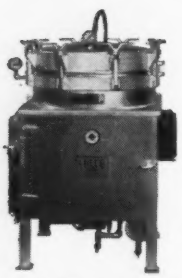

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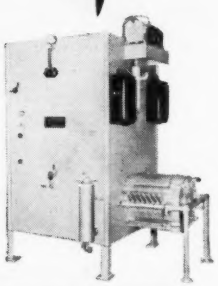

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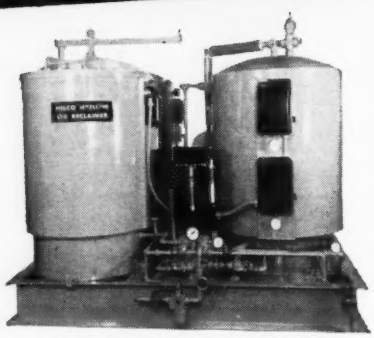

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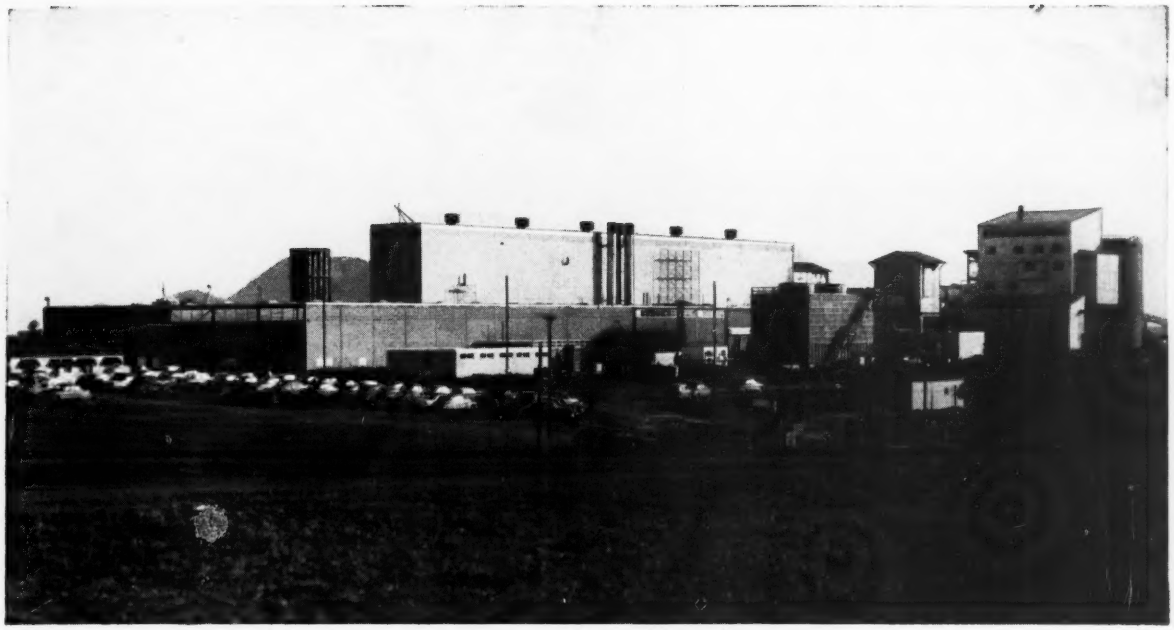

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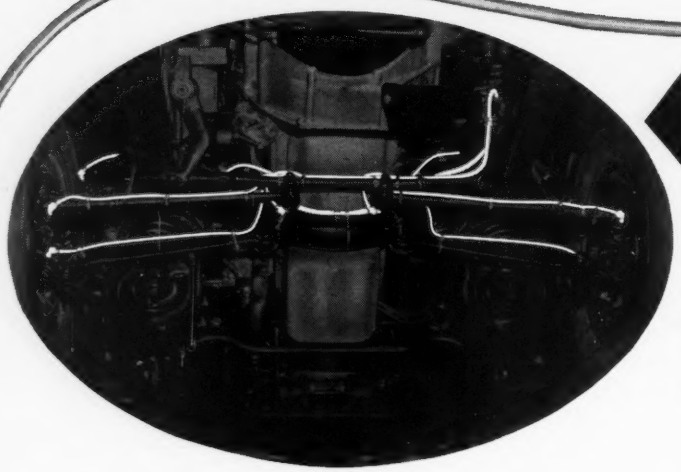

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It's chemically resistant to lubricants and any additives, inhibitors, etc., they may contain.

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"Steel from the Furnaces." Agnes Potter Lowrie depicts some of the basic steel products which provide the sinews of American industry. The I-beam, key piece in building construction. The angle iron. Wire rope. Railway track to carry the carriers of industry. The can, universal container for foods and liquids. And in the background, sheet steel, gleaming symbol of strength and durability. Limited edition of 15 x 18 full-color prints available. Copy on request.

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Too often, estimates of the steel industry concentrate upon our overwhelming productive capacity. Yet more than a little credit is due another American talent—the ingenuity of research coupled with the ever-readiness of steelmen to adopt new and better products and processes.

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Research tackled the problem. Three years ago Ironsides announced Palmoshield as the first domestic replacement for imported palm oil. Within six months two-thirds of our major tin plate mills were using or testing it, often with remarkable results. For example, one company stepped up production 15% with no additional investment, no increase in labor, and no change in mill operation.

Recognized as today's most significant advance in lubrication, Palmoshield offers five distinct advantages:

1. Produced in the heart of the steel industry. Users need not stockpile.

2. Made from freely available domestic materials.

3. Subject to exact chemical control — free fatty acid content to within ½%.

4. Price is not artificial, but fluctuates freely with the domestic fat market.

5. Proved in production to deliver increased tonnage at less cost.

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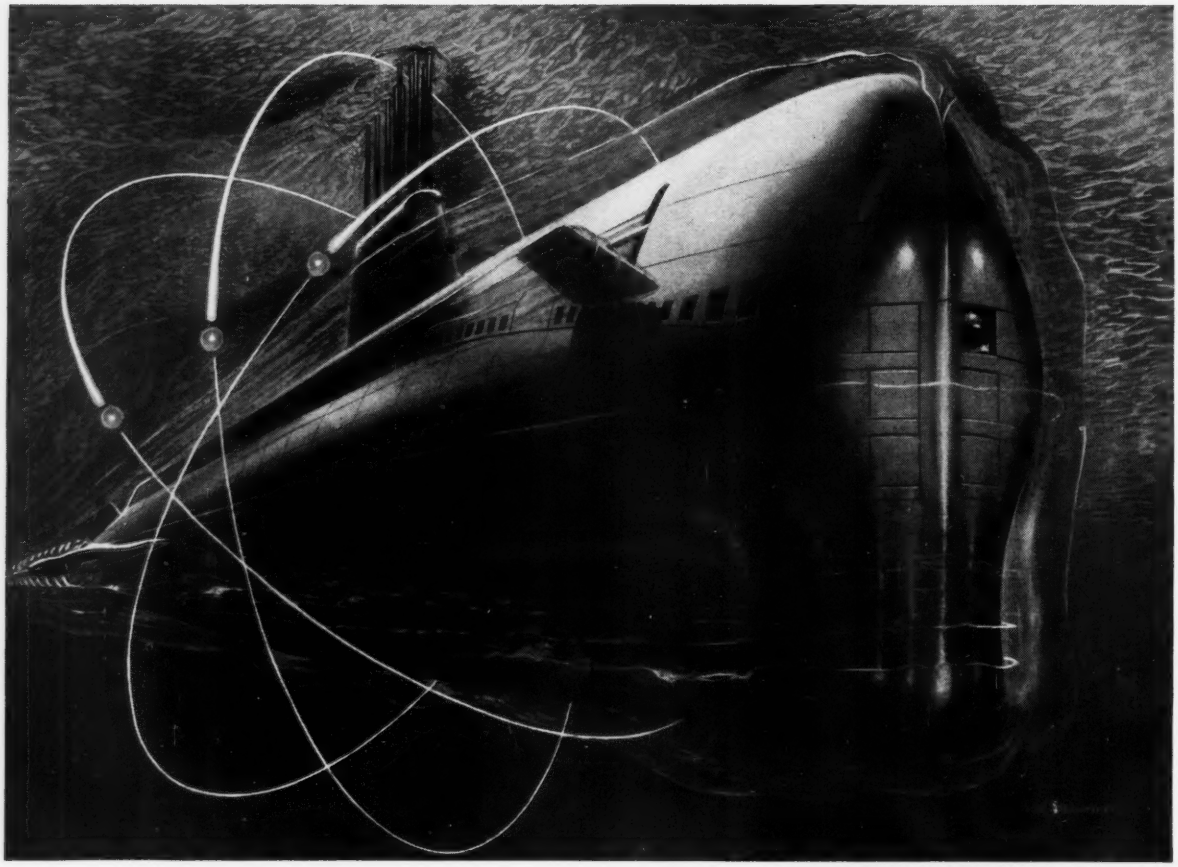

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Atomic Sub and Builders Rely on World's Greatest Lubrication Knowledge

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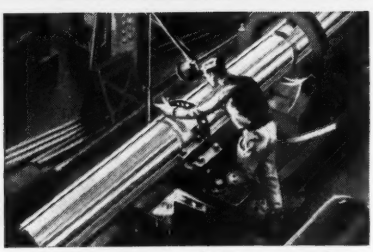
Socony-Vacuum is proud that it has been able to play a dual role in this most significant event.

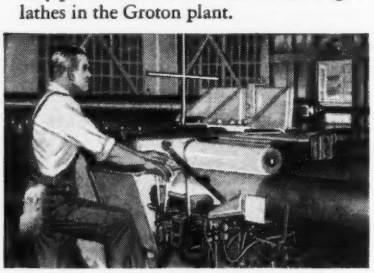
First, famous Socony-Vacuum lubricants are now protecting vital machinery aboard the "Nautilus."

Second, Electric Boat Division, General Dynamics Corp. — builder of the "Nautilus" — relies 100% on our lubricants and a program of Correct Lubrication to protect its plant equipment... has done so for the past 34 years!

We wish the "Nautilus" and her crew all success... pledge our continued cooperation, in every way possible, to the Navy and its suppliers, toward the end of keeping America and her allies strong.



A snorkel intake tube being machined to very precise tolerances on one of the large lathes in the Groton plant.



Hydraulic bender shapes section of 8-in. steel pipe in two minutes. This operation formerly took a full day.

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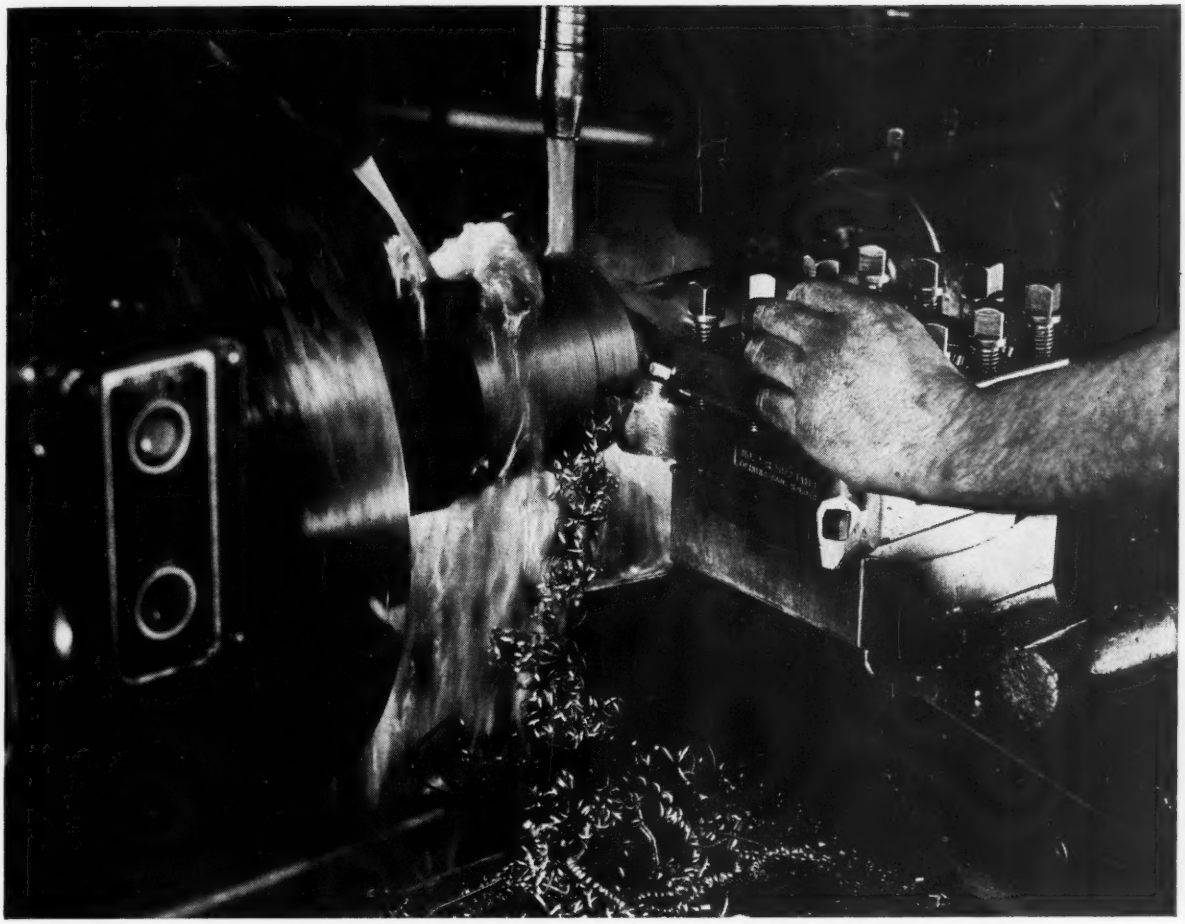

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Liquid Dresinate, available in a number of different types, is described in a recent booklet. This booklet also contains suggested formulations and information regarding selection of the correct Dresinate for emulsion-type oils used in metal working and other fields. Write Hercules Powder Company for your copy.

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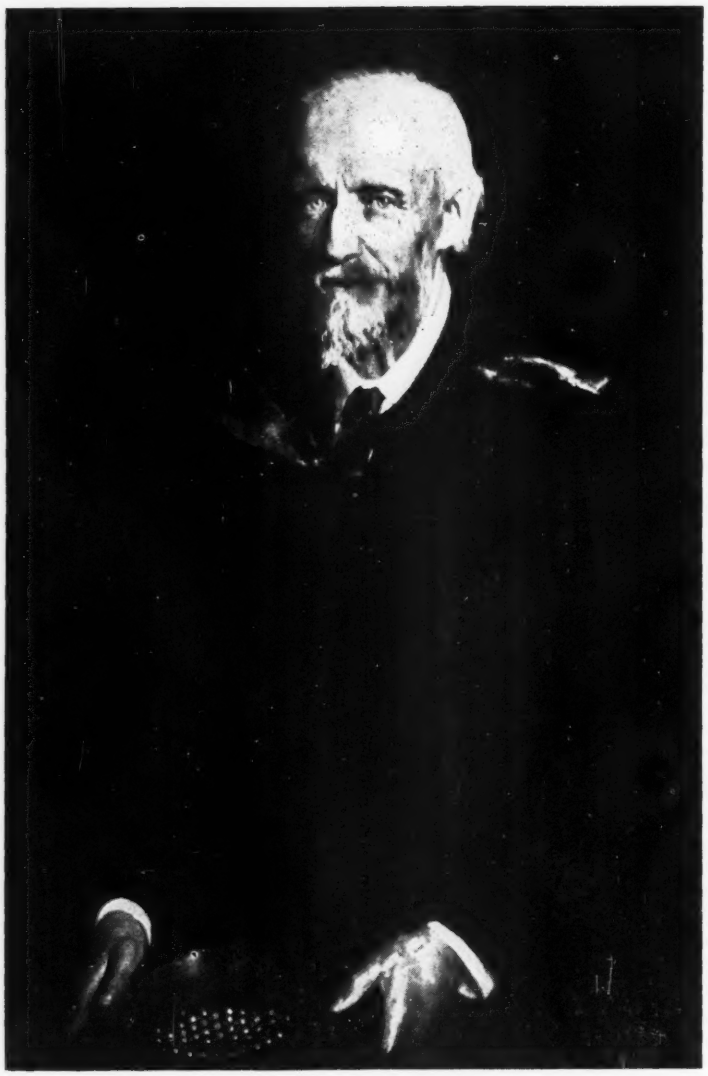

OSBORNE REYNOLDS
from a Portrait by John Collier

(Reproduced by permission of the University of Manchester)

Men of Lubrication

OSBORNE REYNOLDS. In the Science of Mechanical Engineering there is probably no name better known than that of Osborne Reynolds. His contributions cover the entire field and in such a fundamental way that his prominence seems likely to be enduring.

Reynolds was born at Belfast in 1842. His father and grandfather were clergymen in the Church of England, and from his father who took high honors in mathematics at Cambridge he inherited his own considerable talents in this subject. Reynolds graduated from Cambridge in 1867 as Seventh Wrangler. (An honors man placed in the first class in the Mathematical Tripos at Cambridge University.) After a very short employment as a civil engineer he applied and was accepted for the Chair of Engineering at the Owens College, University of Manchester, where he spent the rest of his active life.

During the course of about thirty-five years Reynolds made original and lasting contributions in meteorology, hydrodynamics, lubrication, flow of gases, marine propulsion, and in the application of dynamical similarity to tidal and river phenomena. His large-scale determination of the mechanical equivalent of heat, by using the energy dissipated in a brake on a steam engine to heat water from the temperature of melting ice to boiling, is a work of classical importance in science.

The great contribution Reynolds made in the science of lubrication was a logical extension of earlier work in hydrodynamics. In a classical paper, "An Experimental Investigation of the Circumstances Which Determine Whether the Motion of Water Shall Be Direct or Sinuous and of the Law of Resistance in Parallel Channels," he advanced the science of hydrodynamics in a fundamental way. The great divergence between the findings of Poiseuille and Darcy, the former reporting a head loss in fine bore tubes directly proportional to the velocity, and the latter reporting for pipe flow a dependence on the square of the velocity, was elucidated by this work. It is well known today that the two divergent results were obtained under flow conditions of widely different Reynolds Number, and it was in these papers by Reynolds that this well known criterion was first applied to demark these two distinctly different flow regimes.

In the reports on the friction experiments for the Institution of Mechanical Engineers subsequent to the appearance of Reynolds' famous paper, "On the Theory of Lubrication and Its Application to Mr. Beauchamp Tower's Experiments," there is no mention or acknowledgment of this great work. The omission is so noticeable as to suggest at least a lack of enthusiasm for the massive theoretical interpretation of the committee's findings. And yet, if this analysis had not been made or if such an analysis had not been possible, Tower's work would have been relegated to obscurity and the subsequent developments of Kingsbury and Michell might never have been made. For this reason, and in spite of Tower's precedence, it seems altogether fair to consider Osborne Reynolds the founder of the science of lubrication.

In his great paper Reynolds solved the problem of the inclined plane slider neglecting the side leakage, but unaccountably missed its implication in the troublesome thrust bearing problem on shipboard. This is the more remarkable in view of his extensive work on ship propulsion. His only subsequent reference to lubrication in his published work is contained in a short paper, "On the Slipperiness of Ice." In working with a soldering iron he observed that the hot iron moved along the surface of a piece of solder with virtually no resistance. The similarity of the action to that of a skate on ice immediately occurred to him. The explanation of the easy motion of a skate being a lubrication phenomenon was given in this paper apparently for the first time. The lowering of the freezing point of water by the action of pressure had previously been pointed out by James Thomson, elder brother of Lord Kelvin. Reynolds, from this, deduced the existence of a water film between skate and ice due to the high contact pressure, and the analogy to the soldering iron incident was complete.

Reynolds' contributions to science and engineering are contained in three volumes of his collected papers. They contain a surprising number of scientific developments that are today the working equipment of engineers and physicists as well as rational explanations of many natural phenomena. In the latter category are such things as the explanation of why timbers in buildings hit by lightning are burst asunder. Reynolds attributed it to the sudden evaporation of the moisture present in the wood by the passage of the electricity. The production of steam is sufficiently rapid to amount to an explosion throughout the wood thus bursting it. The explanation of the quieting effect of oil on rough water, as due to eddies caused by relative motion between the contiguous surfaces of oil and water thus dissipating the energy going into wave making, was an outgrowth of his studies on fluid motion. The somewhat similar quieting effect rain has on rough water was also explained by Reynolds as due to each rain drop carrying down into a wave a certain amount of water from the surface. Since the various layers of water in a wave have different velocities, a momentum transfer is effected by the progress of the rain drops. This results in energy dissipation and the violent surface motion is reduced.

These and other similar examples show the breadth of his interest in all that surrounded him and the ingenuity of his mind in providing rational reasons for phenomena of age-old experience. But

(Continued on p. 128)

This is the second in a series of articles by F. R. Archibald, Arthur D. Little, Inc.

SMALL-SCALE LABORATORY EVALUATION TESTS ON SYNTHETIC LUBRICANTS

by F. J. Watson*

Apparatus and procedures are described for small-scale tests of inflammability, oxidation corrosion and thermal stability These tests have been applied to synthetic oils, such as organophosphorous compounds, diesters, silicates, silicones and polygylcols as well as a few low-viscosity oils. Excellent correlation with conventional full-scale tests was obtained in every instance where a full-scale test existed. These small tests are especially useful in evaluating expensive synthetic oils as potential aircraft turbine lubricants, hydraulic fluids, grease-bases and instrument oils. The oxidation-corrosion test is particularly useful in evaluating inhibitors for the synthetic oils under high temperature conditions.

In evaluating expensive laboratory preparations of synthetic oils as possible lubricants it is often essential to employ small-scale tests which duplicate some aspects of full-scale tests. Few such tests are described in the literature. Barker and co-workers[1] mentioned some small-scale tests used to evaluate instrument lubricants but they were not directly applicable to our investigations.

The properties of interest on our compounds and required in most government and civilian specifications for lubricants were volatility, flammability, oxidation, corrosion and thermal stability. Part of the test development was carried out under an Office of Naval Research Contract (ONR Nos. 87,500 and 87,501) on Organophosphorus Compounds but the tests have also been used to evaluate other synthetic lubricants, such as diesters, polyglycols, silicates, silicones, halocarbons and the low viscosity mineral oils.

A modified open cup flash point apparatus was constructed and gave good correlation with the full-scale test. A modified pipe cleaner test was used as one measure of flammability. Oxidation-corrosion stability was determined using a modification of the Federal Specification VV-L-791e, Method 5308.3 for light oils. This test measures the stability of the oil, at elevated temperature and in the presence of catalysts and air, toward formation of acidic products, polymerization with resultant viscosity increase or deposition of sludge, and corrosion of the metals present. Thermal stability (ability of the oil to withstand high temperatures in the absence of air or oxidizing influences) was determined at several temperatures using heavy walled Pyrex tubes in a micro-Carius furnace.

*Shell Development Co., 4560 Horton St., Emeryville 8, Calif.

DESCRIPTION OF TESTS. Flash Point Apparatus. A semi-micro flash point apparatus, patterned after the Cleveland Open Cup, was constructed to have the same exposed area but with reduced depth so that only a 10 ml. instead of a 75 ml. sample is required. A well was provided to hold the thermometer at the usual immersion depth. The comparison between the semi-micro and the full-scale cups is shown in Fig. 1. The excellent correlation with the full-scale test on pure compounds and mineral oils may be seen from the data in Table I. Only in the case of HS-1, the reference standard (of unknown composition) for Aeronautical Material Specification, AMS 3150A, for nonflammable hydraulic fluids, was the correlation poor between the two cups. The two hydraulic fluids, MIL-0-5606 and Skydrol, which are also not pure compounds or straight mineral oils, however, gave excellent correlation. The usefulness of this test, for mixtures in general, is still open to question.

Pipe Cleaner Flammability Test. A pipe cleaner flammability wick test is also described in the AMS 3150A specification mentioned above. This test was an outgrowth of several tests to determine flammability using wicks saturated with hydraulic fluid. Filing cards, glass cloth, and finally pipe cleaners were examined. Fires resulting from combat or airplane crashes may start with the fuel but can be spread to a larger area by the hydraulic fluid if the latter is very flammable and under high pressure. In our modification of the test to improve reproducibility, a pipe cleaner, reduced to 4¼ inches in length,

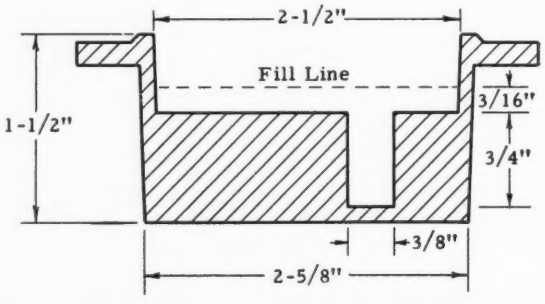

Fig. 1. Modification of Cleveland open cup apparatus. 10 ml, exposed area constant, depth of sample reduced. Semi-micro apparatus used in this work. (See Method 1103 in Federal Specification VV-L-791e for full-scale method.)

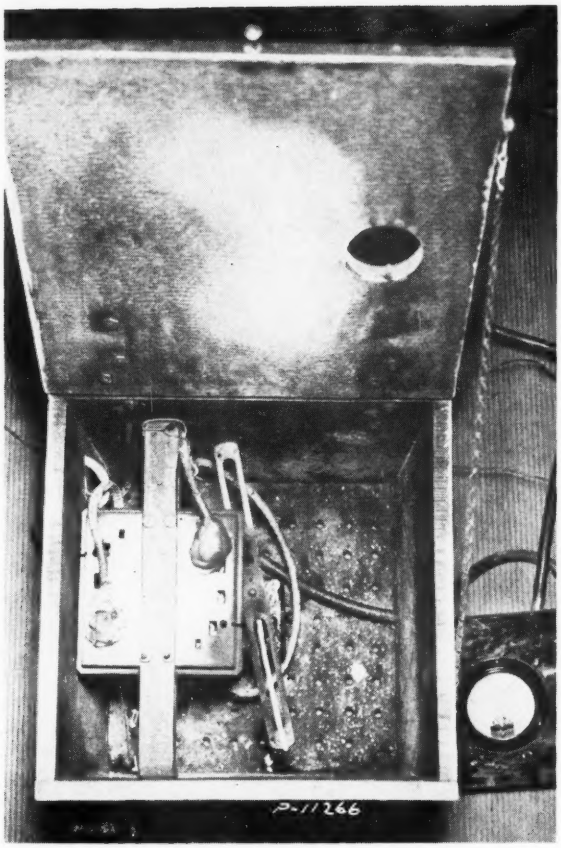

Fig.2. Top view of pipe cleaner test assembly.

is saturated with the fluid to be tested, the excess drained, and the cleaner inserted in a horizontal metal holder. The holder is then cycled at 36 rpm between two electrical hot plates (Thermolain 4-inch square open coil heaters, 550 watt) rather than through a burner as in the specification test. These plates are mounted horizontally about ½ inch apart with a grid of ceramic spaghetti over the open coil heaters. The temperature between the two grids varies between 760 C. and 710 C., dropping during a test. The apparatus is mounted in a transite box, with a hinged cover, and placed in a hood. The cover of the box is in place during the test. A side hole permits visual observations (see photograph in Fig. 2). The cover is removed between tests to change pipe cleaners and clear the vapors and smoke. The number of cycles prior to the first flash and self-sustaining flame are both recorded. At least three tests are run on each sample. If the deviations are too great (above 10%) additional tests are run until the results fall within this limit. The average of the flash points and fire points are used, although the latter is considered more significant. A surprisingly fair correlation with flash or fire points in the semi-micro open cup apparatus and our pipe cleaner test was obtained on various synthetic fluids including phosphorus esters, aliphatic diesters, polyglycols as well as mineral oils. The data are shown in Table II. The pipe cleaner test could be run on samples too small for the semi-micro open cup apparatus.

HS-1 Reference Fluid, available from U. B. Bray Co. for use in AMS 3150A specification, was used as the flammability standard to check the reproducibility of the apparatus from day to day. This standard was run at the start and finish of every series of tests and thus served to indicate a change in temperature between the hot plates. HS-1 fluid usually gave about 10-11 cycles on flash and 16-17 on fire point.

Oxidation-corrosion. The oxidation-corrosion test for light mineral oils (Federal Specification VV-L-791e, Method 5308.3) was modified to use a 20 ml. sample instead of the usual 100 ml. The air flow rate and metal surface area were correspondingly reduced to one-fifth of the standard value in Method 5308.3. Metal washers were used instead of the squares of different metals tied together to form an open cube or pentagon. The washers were fitted over the air inlet tube with glass spacers separating the metals at a convenient distance. A coarse sint-

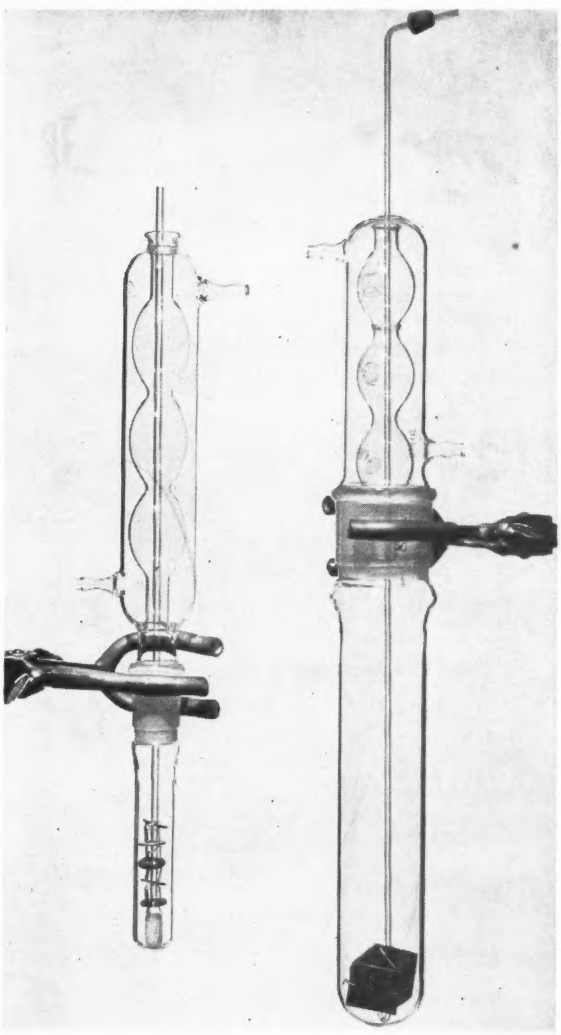

Fig. 3. Oxidation-corrosion cells and arrangement of corrosion strips. Small scale (left); Full-scale (right).

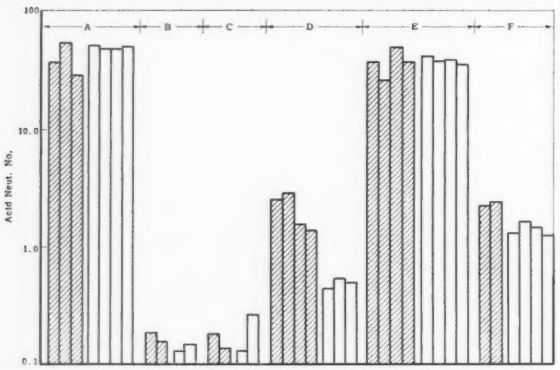

Fig. 4. Acidity of used oils from oxidation corrosion test. See Table III for compound identification. Each vertical represents one complete test; shaded bars represent full-scale (military specification tests); clear bars are from small-scale tests.

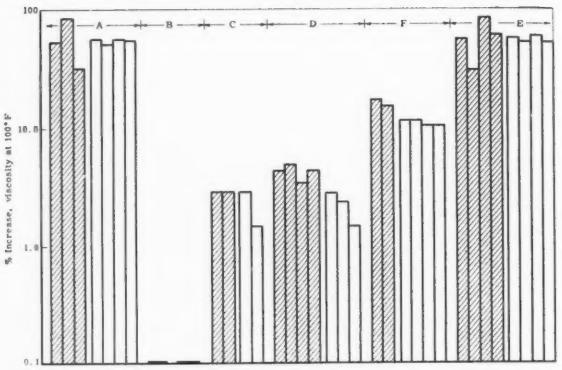

Fig. 5. Viscosity increase of used oils from oxidation corrosion tests. See Table III for compound identification. Each vertical represents one complete test; shaded bars represent full-scale (military specification tests); clear bars are from small-scale tests.

ered glass tip on the lower end of the air inlet tube provided adequate dispersion of the air and uniform mixing around the metal specimens. This arrangement provides excellent circulation of oil around the metals, avoids the mechanical difficulty of tying small specimens and eliminates the possibility of metal to metal contact which can occur between adjacent pairs in the full-scale test. Fig. 3 illustrates the cell and metal arrangements used in the small-scale and full-scale (MIL-0-5606) oxidation-corrosion tests. The copper, mild steel, magnesium and aluminum alloy specimens were polished in the usual manner while the cadmium-plated steel was only washed with solvents as prescribed in Method 5308.3. Air flow to each of the corrosion cells (9 in our bath) was controlled by means of a glass capillary (a short section of thermometer tubing) mounted on a large diameter manifold maintained at constant pressure (about 2 psig). The air was run through drying tubes before entering the manifold and the latter was filled with glass wool to trap dust. Average variation in air flow to different cells was less than 5 per cent.

The cells were connected to a reflux condenser of the Allihn type by means of 24/40 ground glass joints. The cells and condensers were mounted in a rack to hold them vertically and immersed in a thermostatically controlled oil bath. The bath temperature was maintained at 121 C. (250 F.) for the

Table I. Semi-micro and Cleveland open cup flash and fire points of synthetic oils and reference fluids.

Compound	Semi-Micro, °F		Cleveland Open Cup, °F	
	Flash	Fire	Flash	Fire
Trialkyl Phosphate A	340	365	340	370
Trialkyl Phosphonate	385	465	395	465
Trialkyl Phosphate B	410	460	415	465
Mixed Arylalkyl Phosphate	415	430	410	440
Triaryl Phosphate	450	-	455	-
Dialkyl Sebacate	380	415	375	415
Dialkyl Adipate	410	455	400	455
1010 Turbine Oil (MIL-0-6081A)	290	320	295	315
MIL-0-5606 Hydraulic Fluid	230	235	220	225
Nonflammable Hydraulic Fluid (AMS-3150A)	445	470	435	465
HS-1 (AMS-3150A Spec. Ref. Fluid)	435	575	325	430

Table II. Comparison between pipe cleaner and semi-micro open cup flash on organo-phosphorus compounds and other synthetic oils.

	Pipe Cleaner Test No. of Cycles		Semi-Micro Open Cup Test, °F	
	Flash	Fire	Flash	Fire
HS-1, Flammability Ref. ASM-3150A	10-11	16-17		
1010 Turbine Oil (MIL-0-6081A)	2	7	290	320
MIL-0-5606 Hydraulic Fluid	1	1	230	235
Trialkyl Phosphate A	8	13	340	365
Trialkyl Phosphate B	14	16	410	460
Trialkyl Phosphonate	14	16	385	465
Mixed Alkyl Aryl Phosphate	15	20	415	430
Triaryl Phosphate	17	47	450	No Fire Pt.
Trichloroalkyl Phosphate	22	No burning	No Flash or Fire	
Dialkyl Adipate	6	6	335	370
Dialkyl Phthalate	9	13	395	450
Dialkyl Sebacate	14	14	445	495
Poly (Alkylene Oxide)	16	29	525	540

standard test. The test time was fixed at 71 ± 2 hours in order to permit two tests per week in the same equipment. It was found that excellent correlation with the 168 hour full-scale test at 121 C. was obtained on six commercially available phosphorus compounds, representing low, medium and high levels of corrosion in the full-scale tests. As in the latter test, weight loss of metal (mg/cm²), and viscosity change (at 100 F.) and increase in acidity are used as measures of corrosion and oxidation, respectively.

The data in Table III on the phosphorus esters indicate that the degree of oxidation was about equal in the two tests while corrosion of copper was lower and corrosion of the other metals higher in the small-scale test in comparison to that in the full-scale 168 hr. test. The variations in individual tests by each method are shown for the first compound, trialkyl phosphate A, while the averages for 2 or more tests are shown for the other five esters. A similar relationship between the two tests would be obtained with other synthetics. Figs. 4 and 5 show by means of bar graphs the data from Table III on acidity and viscosity increase for the same six compounds. In general the reproducibility in the small-scale test has been superior to that in the MIL-0-5606 (Method 5308.3) test with regard to final acidity and viscosity increase.

For more severe operation, a temperature of 175 C. has been used with the small-scale apparatus. We have again used the same test period, 71±2 hours. Specification MIL-L-7808B Amendment 1 requires a 72-hour test at 175 C. for oxidation-corrosion stability. Method 5308.3 is used and the limits for copper corrosion have been increased to ± 0.4 mg/cm² and silver is used in place of the cadmium-plate.

The small-scale test was also of value in investigating inhibitors for synthetic oils. In most instances the synthetic oils are very unstable to oxidation and corrosion. Suitable inhibitors are therefore required for their application. Many inhibitors, although reducing oxidation and corrosion, increase the amount of sludge or deposits on the corrosion test pieces. This factor is very important in the final selection of the best inhibitor for a given synthetic.

In some instances the oxidation of the oil in the high temperature test has resulted in stable foams which continue up the tube and over the top of the reflux condenser, resulting in a high loss of samples. The addition of a drop of silicone anti-foam has usually avoided this difficulty.

Thermal Stability. To determine what changes might take place with synthetic lubricants when subjected to high temperatures in the absence of oxygen several series of experiments were carried out using heavy walled Pyrex tubes in a micro-Carius furnace at 200 C. The sample size was 20 ml., the heating time was 20 hrs. and nitrogen was used to sweep out the air. The data for several phosphorus compounds are given in Table IV. Compared to a diester, the phosphorus compounds have poor thermal stability.

The thermal stability of synthetic oils under higher temperature has been investigated with a modification of the conditions of the above-described

Table III. Oxidation and corrosion tests on phosphorus compounds, 250 F. (Note: + sign indicates weight gain not loss.) Capital letters show identification of compounds in Figs. 4 & 5.

Sample	Type of Test	Weight Loss, mg/cm² Cu	Mg	Fe	Cd	Al	Final Acid Neut No.	% Inc. $V_{100°F}$	%w Oil Loss
A Trialkyl phosphate	MIL-0-5606	7.91	7.02	0	3.17	0.02	37.1	56	3.2
	"	11.2	6.05	0.01	3.08	0.01	54.2	90	6.1
	"	3.14	0.02	+0.19	0.87	+0.03	28.6	33	1.1
	71 hr. small-scale	5.0	10.6	0.08	3.44	0.20	50.3	59	0.6
		1.56	5.91	0.12	27.0	0.16	48.4	53	0.6
		1.84	7.6	0.08	14.2	0.12	47.2	58	2.2
		3.03	8.7	0.32	14.4	0.24	48.3	57	2.2
	Average MIL-0-5606 large-scale	7.41	7.36	+0.06	2.37	0	40.0	59.7	3.5
	Average 71 hr. small-scale	2.86	8.20	0.15	14.76	0.18	48.5	56.8	1.4
B Trialkyl phosphate	Average MIL-0-5606	0.45	0.11	0.02	0.03	0.02	0.18	0	1.4
	Average 71 hr. small-scale	0.46	0.10	0.14	0.12	0.12	0.14	0	0.3
C Triaryl phosphate	Average MIL-0-5606	0.21	0.03	0.02	0.10	0.02	0.16	3	0.4
	Average 71 hr. small-scale	0.34	0.12	0.16	0.16	0.16	0.20	2.2	0.3
D Mixed Aryl Alkyl phosphate	Average MIL-0-5606	7.61	0.05	0.01	0.22	0.01	2.08	4.4	0.9
	Average 71 hr. small-scale	0.89	0.01	0.05	0.60	0.09	0.49	2.3	1.4
E Trialkyl phosphonate	Average MIL-0-5606	20.9	0.03	0.01	0.09	0.01	37.0	61	3.1
	Average 71 hr. small-scale	4.39	0.22	0.17	7.74	0.15	37.7	57	1.1
F Mixed Alkyl Aryl phosphonate	Average MIL-0-5606	3.75	0.01	0.01	4.58	0	2.26	17	2.6
	Average 71 hr. small-scale	1.81	0.05	0.16	1.47	0.17	1.35	11.5	1.2

Table IV. Thermal stability of synthetic oils, 20 hrs, at 200 C. (Note: Changes in viscosity at 100 F. and in VI are also routinely determined in this test but are omitted in this table for the sake of brevity.)

	Viscosity in Centistokes			Final
	Original Oil V_{210}	Used Oil V_{210}	% Inc. V_{210}	Acid Neut. No.
Dialkyl Adipate	1.70	1.73	2.0	0.31
Trialkyl Phosphate A	1.69	1.70	0.5	12.0
Trialkyl Phosphate B	2.97	2.51	-15.5	32.2
Trialkyl Phosphonate	3.85	3.73	-3	4.83
Bis(Dialkyl phosphono) Alkyl ether	2.89	3.20	10.5	18.9
Mixed Aryl Alkyl phosphate	2.45	15.72	542	157

test using the micro-Carius furnace. In this test the sample, 18 g., is blanketed with CO_2 and each tube fitted with an air condenser, about 11 inches long. The tubes are placed in the furnace at 288 C. (550 F.) and held at this temperature for 6 hours. (The temperature drops 10-15 C. but returns to 288 C. in about ½ hour after the tubes are inserted in the furnace.) The tubes are removed and observations recorded as to deposits above liquid level. The weight loss is recorded and change in viscosities and acidity determined on the used fluid.

Under these more severe conditions, the diesters showed little change in viscosity but appreciable increase in acidity while a mineral oil, silicone, silicate and inhibited polyglycol gave little change in viscosity or acidity. Two other polyglycol samples gave appreciable viscosity change but no increase in acidity while the phosphorus esters exhibited poor thermal stability, especially the trialkyl phosphates.

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ACKNOWLEDGMENTS. The author is indebted to Leo Grenot, technician, for the construction of several of the test apparatus and to Miss Marjorie Chew for the test data reported herein. S. K. Talley also contributed ideas on arrangement of metals in the corrosion test. G. T. Price designed the semi-micro flash point apparatus.

Current Literature

Dow Corning 41 Grease. Performance data on this silicone fluid-carbon black mixture designed for high temperature, slow speed bearings, is featured in a recently released brochure in the form of illustrated case histories detailing actual savings in relubrication schedules, replacement and maintenance costs. Applications discussed include oven conveyor bearings, dolly wheels, injection valves, permanent casting machines, extruder hold-down bolts, and turbine governors. Specifications and typical properties are also given. (Dow Corning Corp., Midland, Mich.)

Weatherhead "Yellow Book." A new composite industrial products catalog has been issued containing valuable information for designers of hydraulic and pneumatic control systems. Arranged for quick reference, its tabbed pages indicate separate sections covering brass tube fittings, drain and shut-off cocks, SAE 37° flare (JIC) fittings, Ermeto steel and stainless steel fittings, bulk hose and reusable ends, and hose assemblies (with reusable or permanently-attached ends). A "Technical Data" section includes pressure tables, tube bending instructions, correct procedures for making hose assemblies, hose end hex sizes, tubing safety factors, and tube wall thickness tables. A section covering service tools and equipment is also included. (The Weatherhead Co., 300 E. 131st St., Cleveland 8, Ohio.)

"Colloidal Graphite as a Parting Compound." A new illustrated bulletin, No. 427, discusses the use of "dag" colloidal graphite as a parting compound. Because "dag" dispersions possess unique physical properties which minimize corrosion and metal pick-up, and prevent sticking, galling and freezing of parts, they are being used as release agents for glass molding, on clutch plate separators, as anti-weld coatings and gasket coatings, as anti-seize for screw threads, in corrugated boxboard manufacture, rubber molding, foundry work and other industrial operations. Specific "dag" dispersions for many industrial uses, and techniques of application (including the new stencil pattern application for controlled welding) are presented. (Acheson Colloids Co., Port Huron, Mich.)

Redesigned Water Washout Grease Tester. Data Sheet #11498 discusses applications of the redesigned water washout grease tester (an apparatus for evaluating the resistance of lubricating greases in a rotating bearing to washout by water), as well as its outstanding features of temperature control, adjustable water flow, ease of cleaning, and ease of removal and replacement of the test bearing. (Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.)

"Filter Fabric Facts." A new illustrated booklet summarizes a number of general and specific facts about filter fabrics which have not been generally available to the processing industries in any one publication before. Based on the Company's fabric development files and the experience of specialists in various aspects of filtration, it contains information about filtration principles, filter-

(Continued on p. 131)

INTERPRETING BALL BEARING DAMAGE

by B. J. Dempsey*

Many types and causes of ball bearing damage have been presented in the literature, the most recent comprehensive survey being that of H. O. Walp ("Interpreting Service Damage in Rolling Type Bearings," ASLE Publications). The present paper is intended to supplement the existing information with additional examples of types of damage and to describe the use of the noise test machine in determining the particular ball bearing trouble. Noise testing, which has not been previously discussed, has become an important part of diagnosing bearing troubles.

TYPES & CAUSES OF BALL BEARING DAMAGE. One of the most common causes of bearing damage results from improper handling or mounting of the bearing. This type of damage is shown in Fig. 1 and is most prominent in installations where final assembly of units must be accomplished through the insertion of bearings (which already are assembled on shafts) into housings. A typical example is an endbell on a small fractional h.p. motor. Damage occurs when axial pressure is applied to the shaft. If fits are tight or bearing is cocked, the load necessary to insert the bearing pushes the balls high up on the races and creates a triangular-shaped dent or Brinell spot at the junction of the raceway with the shoulder.

When this damage takes place in the raceway, a corresponding mark or crease occurs on the ball surface (Fig. 2). Usually this is the direct cause of noise in the bearing. The sound resembles a rattle which changes to a whine as the speed of the bearing is increased. It is produced when the damaged portion of the ball hits the raceway surface. As a rule, the balls do not ride over the race Brinell as this usually is high enough on the raceway so as to be out of the contact area. Prevention of this type of difficulty is accomplished: (1) by making sure bearing fits, particularly those in the housing, are correct; (2) by providing the assembly operator with the proper tools so as to insure bearings are pressed on the shaft through the inner ring and into the housings through the outer rings; and (3) by eliminating use of hammer, drifts or methods that would tend to abuse bearings.

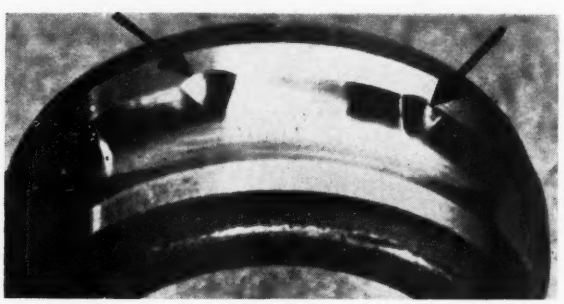

Fig. 1. Damage to bearing raceway by improper mounting.

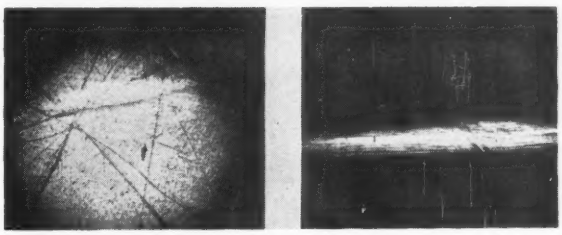

Fig. 2. Damage to ball by improper mounting.

Fig. 3 shows the effect of a loose shaft fit in a bearing bore. In this case, the fit was loose enough so that actual rotation of the inner ring on the shaft occurred. Such an action usually produces a considerable amount of free iron from the shaft surface. This material then gets into the bearing which results in noise and premature failure. When the fit is only slightly loose, fretting or galling sometimes occurs due to slight motion without actual turning of inner ring on the seat. A small amount of this does not necessarily cause harm to the bearing but when the condition is excessive, the action produces iron oxide. This material then acts as an abrasive to cause wear in the bearing. The same trouble, of course, occurs in housing seats in applications where this housing is the rotating part. If the fit between

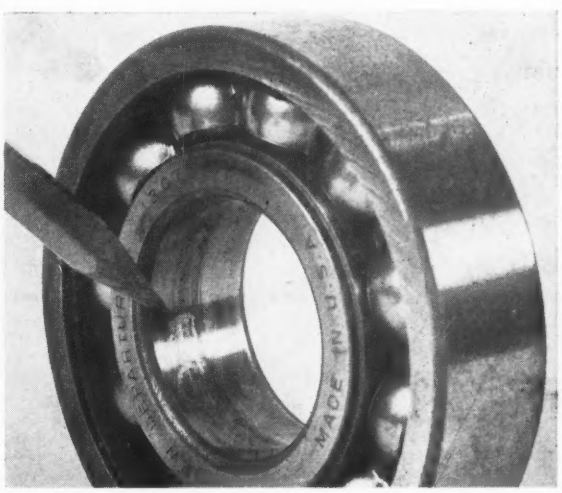

Fig. 3. Damage to bearing bore resulting from a loose shaft fit.

*New Departure Div., General Motors Corp., Bristol, Conn.

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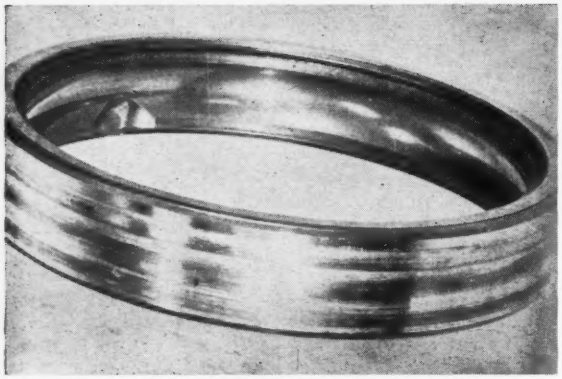

Fig. 4. Damage to bearing outside diameter resulting from a loose fit in bearing housing.

the outside diameter of the outer ring and the housing becomes loose or was loose initially, the same situation results as in the case of a loose shaft fit. This is shown in Fig. 4. Frequently excessive rotation of the ring in its seat results in cold working and even cracking the bearing. The obvious conclusion is that whenever possible, the revolving bearing race should be a tight fit in its seat.

Bearing cracking may occur when fits are excessively tight. Usually this occurs when the bearing is mounted or shortly thereafter. The high impact stresses at the cracked section in the raceway cause rapid breakdown of the race surface at this point. Failure in the raceway usually is on the side toward the direction of ball rotation. In most cases ball bearings are flexible enough to absorb a tight fit unless it is prohibitive. In such cases, expansion of inner and contraction of outer ring may cause an internal preload in the bearing.

Although the turning of a bearing ring on its seat results from loose fits, it may also occur when the finish on the bearing seat is rather coarse. In this case, the finish soon breaks down so that the same condition of loose fits eventually takes place.

Another condition contributing to fretting of bearing seats is intermittent high thrust loads in applications where bearings are not axially clamped. Here, the fretting may occur from the combination of the load and from motion on the seat from shaft deflections. Here again, prevention of the trouble is accomplished by insuring correct bearing fits on shafts and in housings. Care should be taken in the

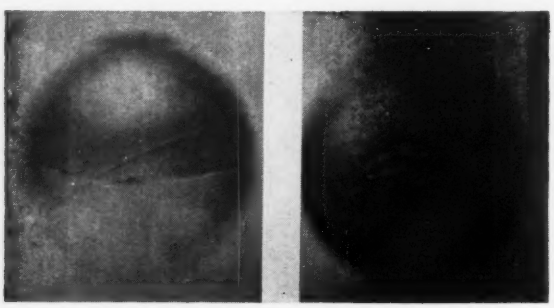

Fig. 6. Damage to ball by misalignment.

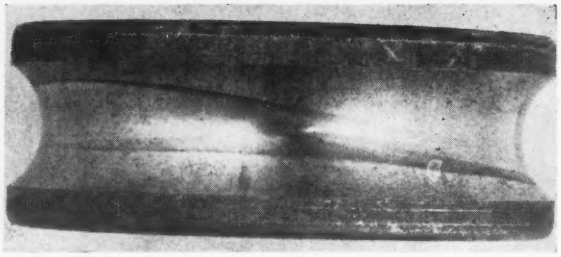

Fig. 5. Wear caused by misalignment.

design so that adequate bearing support in the form of shaft and housing shoulders is sufficient. Axial clamping of bearing is always a must where any appreciable thrust or loads that tend to cause deflection of adjacent parts is present.

Out-of-roundness of housing brought about by distortion of the parts when clamped together or due to general poor machining of the housing itself has resulted in the early flaking of the outer raceway at the points where the squeeze occurs. Considerable retainer pocket wear is apt to occur. Such wear then causes the retainer to drag to an excessive degree on the inner ring O.D. and in the outer bore.

Another source of retainer trouble is misalignment in bearings (see Fig. 5). This illustration shows effects of a bent shaft on a ball bearing. The load track veers from one side of the race to the other and the cycle is completed in one turn of the inner ring. A similar condition could also result if shaft shoulders or clamping nuts were out of square with the bearing seat. Here again, preliminary indications of the trouble may be indicated by retainer looseness due to wear from the high stresses set up in pockets by the misaligning action.

Fig. 6 shows corresponding damage to balls when excessive misalignment is present. The creased section on the ball surface which occurs when the misaligning load forces the ball over the shoulder edge for a portion of a revolution. Failure usually shows up on the ball at the junction of several creases.

Another cause of race surface damage in bearings is the so-called "false" or "shipping" Brinell, Fig. 7. Trouble of this nature usually takes place in

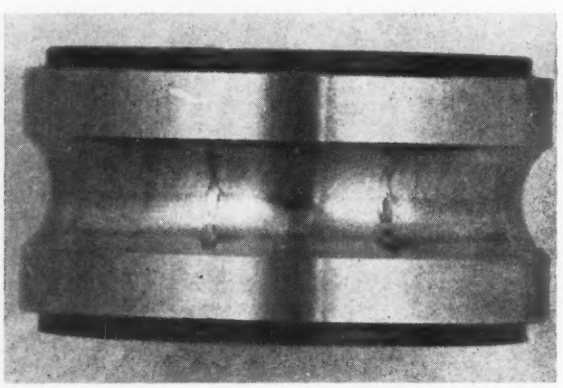

Fig. 7. False Brinelling resulting from damage to raceway in shipping.

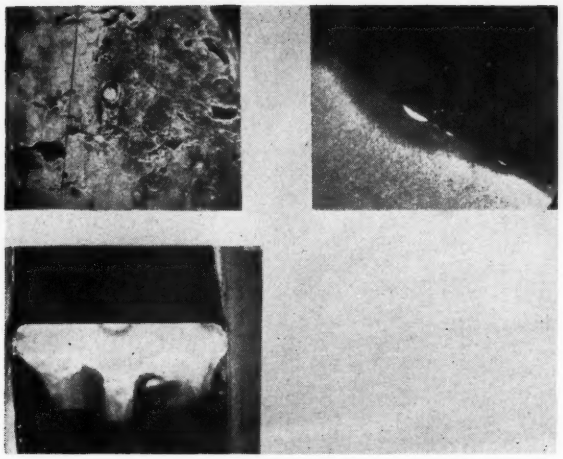

Fig. 8. Damage to raceway and outside diameter resulting from stray electric currents.

rail or driveway shipments of cars or other machines when bearings are heavily loaded either by preloading or by overloading in securing the job for shipping. Movement of the ball in the raceway which is produced by shipping vibration creates iron oxide and actual wear at ball-spaced intervals in the bearing race. Reduction of bearing loads and introduction of lubricants of higher film strengths help eliminate complaints of this nature.

Fig. 8 shows raceway damage of a type resulting from a short circuit through the bearing. The fused spots produced resemble weld spatter. Actual tempering takes place under the race with a hardened area created at the surface. In subsequent operation, this whole affected section separates from the raceway.

The action of an abrasive in a bearing can usually be identified by extreme axial looseness in the bearing without any actual failure. Balls and races ordinarily show a dull, gray discoloration as contrasted with the bright lustrous initial finish. Sometimes when the abrasive is of a particularly fine nature, the finish created by the action is as bright or brighter than that produced originally.

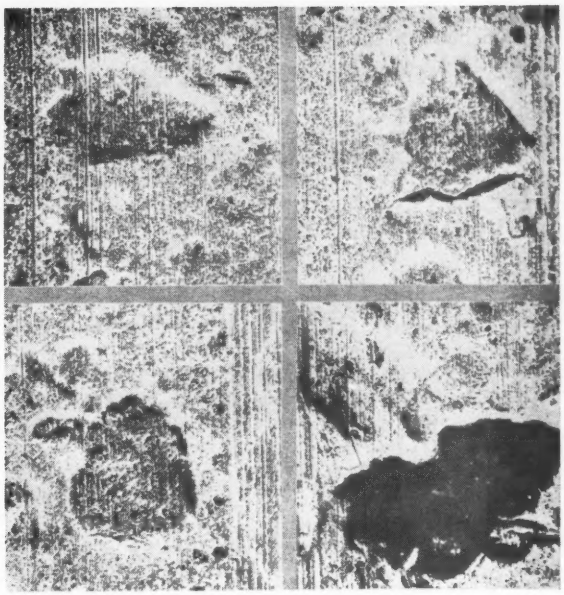

Fig. 9. Raceway surface damage produced by dirt in the ball bearing. 9a (upper left); 9b (lower left); 9c (upper right); 9d (lower right).

Another big cause of bearing rejection and failures in the field undoubtedly results from the introduction of foreign material into internal bearing parts. Fig. 9 shows the evolution of a dirt failure as produced in the laboratory. Fig. 9a shows the indented inner raceway caused by the ball passing over a hard particle magnified 100 times. The depression caused by this action can be readily seen. Fig. 9b was taken some time afterwards by marking the original indent and continuing to run the bearing. This shows a small crack beginning to open up adjacent to the indent. The crack has not occurred in the indented area but is actually outside of this

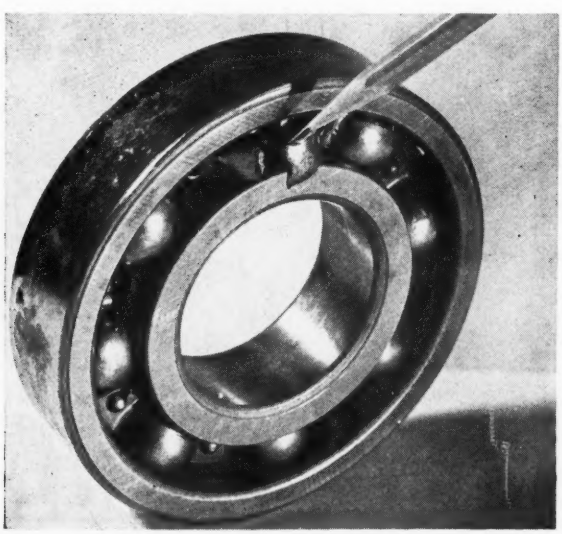

Fig. 10. Damage to retainer by lack of lubrication.

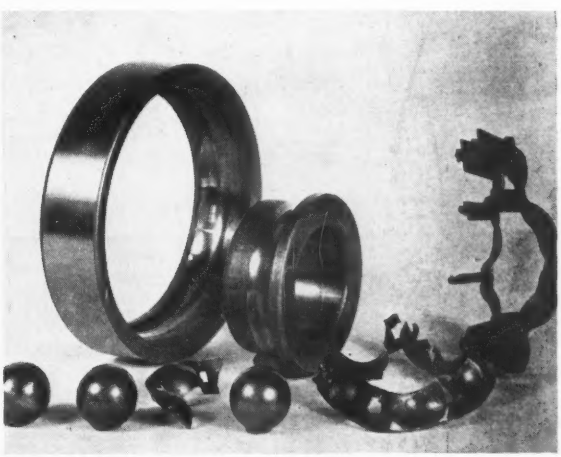

Fig. 11. Complete failure of retainer by lack of lubrication.

Fig. 12. Failure of bearing due to improper or inadequate lubrication.

part. It is believed that this results from the ball hitting the burr at the edge of the indent and stressing the adjacent material to the point of cracking. This bearing was again reassembled and run for another 30 hours in the laboratory.

Fig. 9c shows the result. The crack has now opened up to a considerable extent and spalling appears to be imminent. Actually, Fig. 9d which was taken after an additional 30 hours run shows that the crack has opened through the spalled area. Prevention of bearing failure by entry of abrasives or dirt is usually accomplished by a review of the application with regard to efficiency of closures. Sometimes the addition of a slinger in cases where the bearing seal is the sole closure used, is sufficient to eliminate the trouble. The slinger used on pump shaft bearings to eliminate water is a good example of this. There may be times when it becomes necessary to review bearing handling procedures prior to mounting, initial cleanliness of housing and other adjacent parts to eliminate the condition.

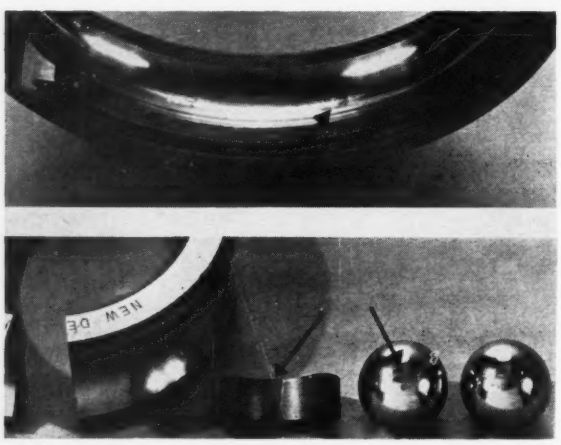

Fig. 14. Failure of a ball bearing race due to inadequate lubrication.

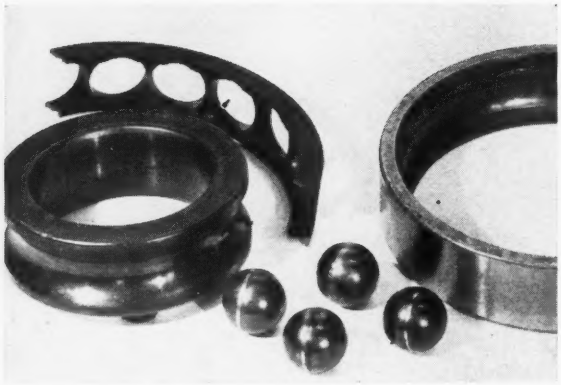

Fig. 13. Failure of a phenolic retainer due to lack of lubrication.

Although bearing misalignment and housing out-of-roundness are causes of retainer failure, lubrication trouble probably is the most frequent reason for separator failure. Fig. 10 illustrates a more advanced condition of poor lubrication in a single row bearing with steel retainer. The retainer has actually broken at one ball pocket and complete failure of adjacent parts is imminent. Fig. 11 shows a final retainer failure. Here the steel retainer is broken and distorted although actual damage to races and balls is not too serious. Fig. 12 shows a bearing failure also resulting from continued operation in the presence of poor or scant lubrication. The retainer parts are broken, balls and races show tempering and inner ring face has actually buckled due to combination of tempering and thrust loads of

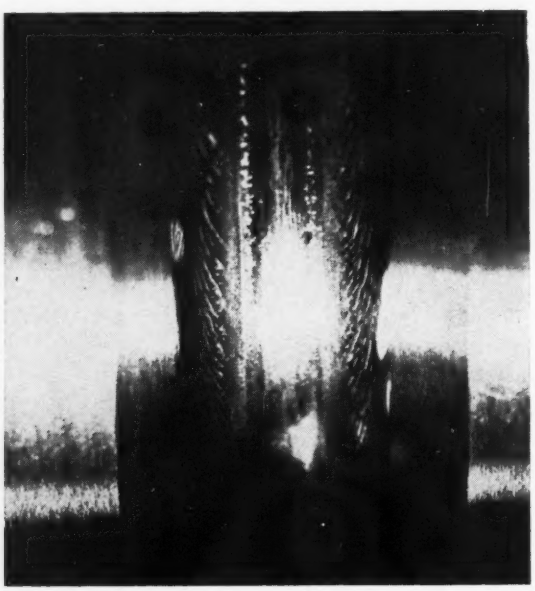

Fig. 15. Failure due to overloading bearing or to inadequate load-carrying capacity of grease lubricant.

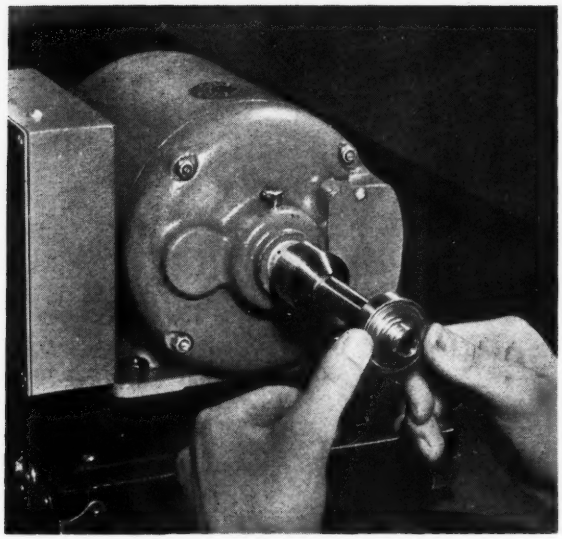

Fig. 16. Method of making a test for bearing noise.

the application.

A non-metallic retainer of the phenolic type, although absorbing considerably more oil than the steel type, becomes brittle and fails in much the same manner as steel separators when the lubrication is not adequate. Fig. 13 shows a non-metallic retainer failure where actual breakdown has occurred. It will also be noted that balls and inner rings are considerably discolored. This is attributed to the porous quality of the non-metallic type of retainer which may continue to partially lubricate the bearings for some time without failure where breakdown of the lubricating system has resulted.

Fig. 14 illustrates a race condition which usually results from rapid acceleration in the presence of little or no lubricant. Actual scoring or galling of the race has resulted due to the breaking down of the oil film at the instant of acceleration. The best means of eliminating lubricant failures is, of course, to design the system so as to insure positive bearing lubrication at all times. In some cases where service is intermittent, the flow of lubricant may not reach bearing until some time after the machine is started. This also results in bearing damage as shown in Fig. 14.

In some applications where bearings were mounted vertically and heavily loaded, some damage of this nature results when the pumping system is such that a lag occurs between the time of starting and actual delivery of oil to the bearing surfaces. Trouble usually is corrected by use of catch basins at the bearings and in other cases by partly submerging bearings.

Bearings lubricated with grease sometimes show the type of failure illustrated in Fig. 15, when loads are heavy and the film strength or load-carrying ability of the lubricant is inherently poor or becomes so from dilution or infiltration. The same appearance is shown by preloading bearings excessively by tight fit-ups as mentioned earlier. Although not too much is known about this type of failure, it has been found that the action produces large quantities of iron oxide which results in ball and race wear and galling as shown in the figure. By introducing a grease having an oil of a higher viscosity, it has been possible to produce satisfactory results in identical applications where the above-type of failures have occurred.

USE OF NOISE TEST MACHINE. Running qualities of ball bearings are generally checked on a noise test machine. Although there are various types in use, most machines consist essentially of a spindle driven directly or indirectly by an electric motor. Spindles may be tapered so as to drive bearings by contacting bore or straight shouldered to drive through inner ring face. They serve to turn the bearing inner ring while the outer is held stationary by an operator. Speeds are generally moderate. Sufficient pressure must be used to prevent ball skidding which results in damaged races and balls. Operators usually apply pressure by placing the thumbs at two points 180° apart on the face of the outer ring (see Fig. 16). In this manner misalignment can be avoided.

The noise test machine should be located in a quiet room insulated from outside sounds. In noise testing, consideration must be given not only to the established noise level but also to existing bearing vibration. In testing used bearings for causes of noise, bearing service personnel have learned to recognize certain types of noise as indicative of a particular bearing trouble. For example:

A harsh, metallic sound generally indicates fine indentations in raceways and balls due to operating the bearing in the presence of hard foreign particles.

An intermittent crackling sound usually indicates dirt in the bearing.

A continuous metallic rattle, produced by the bearing retainer, is caused by running a ball bearing dry.

A high pitched whine usually results from mounting damage such as Brinelling. The sound can be intermittent or continuous depending upon the degree of damage.

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Experiment & Experience

Biological Oxidation Of Soluble Oil Emulsions, by H. Pivnick, M. Fuller, H. Graham & S. Uyeno, University of Nebraska, Bessey Hall, Lincoln, Nebraska.

The Warburg apparatus has been extensively used by bacteriologists and biochemists for the past quarter-century for study of tissue metabolism. With this apparatus research data, which can be obtained only with difficulty by other methods, is frequently obtained quickly and easily. The apparatus is essentially a closed vessel, containing tissue and substrate, attached to a manometer. Oxidation of the substrate by the tissue utilizes oxygen and the oxygen uptake is measured manometrically. For detailed information on use of the Warburg apparatus consult Umbreit, Burris & Stauffer[1].

Certain types of bacteria grow well in soluble oil emulsions[2] and pure cultures of bacteria can be readily isolated from this source. These bacteria, cultivated in beef extract-peptone broth and separated from the media by centrifugation, can be added to the Warburg apparatus as a source of respiring tissue.

The susceptibility of soluble oil emulsions to microbial oxidation can be determined within an hour by adding a few ml. of the emulsion to the cells and noting the amount of oxygen consumed. Fig. 1 shows the oxygen consumed by cells of a pure culture of bacteria oxidizing five different soluble oils. Oil V is oxidized most rapidly, and oil F least rapidly. The endogenous respiration (cells without added substrate) is designated Endog.

This method of study should be of considerable value to oil chemists who are compounding soluble oils. For example, the susceptibility to oxidation of oils made with different emulsifiers could be readily obtained. Also, the effect of such factors as pH, size of oil globule, aeration, etc., would be easily observed. In our laboratory the effect of added nitrogenous compounds on oxidation of soluble oils has been studied by Okawaki[3].

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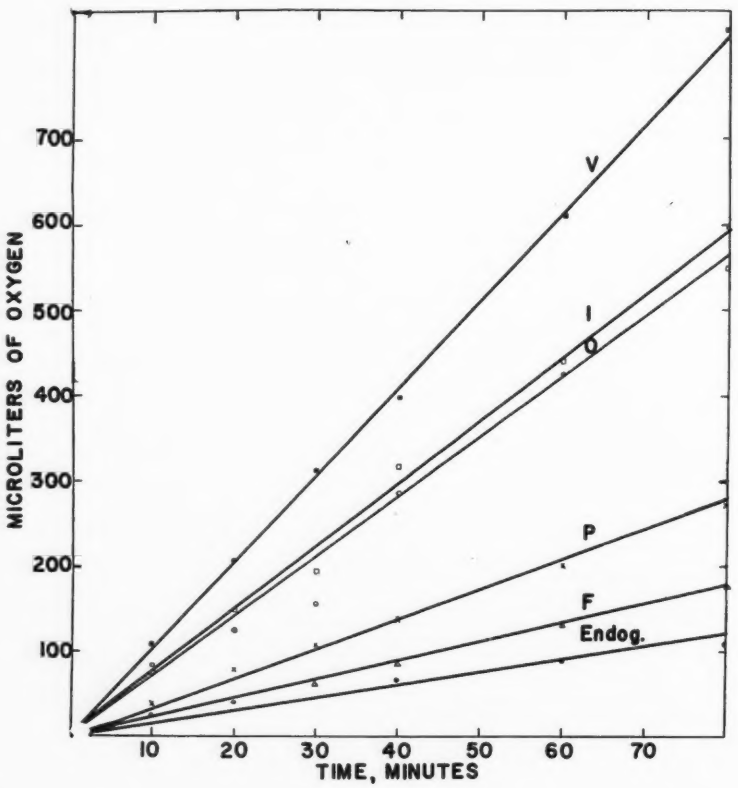

Fig. 1. Oxygen consumption by bacteria in the Presence of five different soluble oil emulsions.

Personals

G. Peters has been elected Chairman of the Board of Directors of Oil-Kraft, Inc., Cincinnati, with **J. R. Bunnell** as President, **R. L. Peters** as Vice-President & Treasurer, and **M. J. Kabbes** as Secretary & General Manager.

G. H. Morehouse & L. P. Smoot, owners of Morehouse Industries, Los Angeles, have purchased **Cowles Dissolver Co.**, Cayuga, N. Y.; **H. N. Meyer, Jr.**, will serve as General Manager.

C. A. Norgren Co., Denver, announce the following appointments: **C. N. Norgren,** as Executive Vice-President; **D. G. Faust,** as Vice-President in Charge of Sales & Advertising; **L. H. Norgren,** as Vice-President in Charge of Engineering & Production; **G. L. King,** as Treasurer; and **J. A. Wilson,** as Chief Engineer.

A. A. Cambere has been named Assistant to B. Archambault, President of Stewart-Warner Corp., Chicago.

The name of **Honan-Crane Corp.**, Lebanon, Ind., has been changed to **Houdaille-Hershey of**

(Continued on p. 130)

FRICTION & FRETTING WITH SOLID FILM LUBRICANTS

by E. E. Weismantel*

The results of a testing program involving the effect of dry film type lubricants on the occurrence of fretting and upon the frictional properties of materials are presented. The data indicate a significant difference in performance of the compounds, the properties being dependent upon both binders and lubricating solids. Under these tests the pure lubricants performed as well as the best of the complex compounds. The significance of operating conditions upon the choice of lubricant and expected service is stressed.

Dry or solid film lubrication has become increasingly important in recent years, and there is a growing need of this class of lubricant in cases where the use of the more conventional liquid lubricants is impractical because of loading or geometrical considerations. Since dry film lubricants showed particular promise for certain parts of aircraft power plants, and also because they have been relatively unexplored, the Aviation Gas Turbine Division of Westinghouse Electric Company set up a comprehensive program to evaluate their usefulness.

Initial studies were made to determine the effectiveness of solid film lubricants in lowering the coefficient of friction and in promoting fretting.

Fretting is a most serious problem since it occurs on parts of machines under conditions of limited movement between closely fitted parts. If no movement occurs, there is no fretting while, if the relative motion is large, other factors enter and the problem becomes one of conventional rubbing of lubricated or unlubricated surfaces.

Fretting is most easily recognized on ferrous metals by the formation of a brownish red debris. However, this type of deterioration of surfaces is by no means limited to the ferrous metals, although the debris formed with other metals is not so easily noticed as that with ferrous alloys. There seems to be no combination of metals that will not be damaged by fretting corrosion, although there is a variation in the tendency to fret between the different metals and alloys[1,2]. Fretting damage has previously been observed to occur regardless of the presence of lubricants[3].

Most authorities who have studied fretting corrosion agree that the damage appears to be increasingly severe as the original fit of the two surfaces is reduced. The corrosion is not uncommon on such locations as between bearing races and their mating shafts, bearings and their races, mating gears, aircraft gas turbine blade roots, universal linkages and associated highly-finished parts. More effort is now being expended on fretting prevention because of the tendency of the corrosion to loosen needed tight fits and because the notches formed during fretting are possible nuclei for the start of fatigue failures.

TESTING PROGRAM. The initial testing under the program was performed on equipment of the type shown in Fig. 1. This design was chosen because it approximates quite closely the contact areas present in the blade roots of certain gas turbines. The assembly consisted of two grooved aluminum blocks (A14ST-6, 135 Bhn) clamped around a 12% chrome steel pin (heat treated to a hardness of Rc22). The ends of the pin were brazed into the yoke and the pin was clamped between the aluminum blocks as shown.

The coefficient of static friction data was calculated from the force just capable of causing movement in the pin block assembly.

Fretting corrosion data were obtained by vibrating the assembly at approximately 11,000 cycles per minute until a maximum of 15 million cycles was

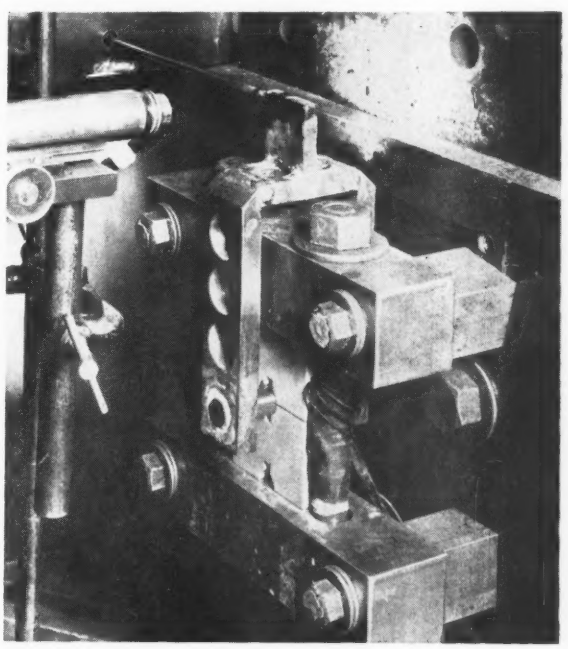

Fig. 1. Fretting corrosion equipment for investigation of fretting corrosion on mating curved surfaces.

*Piasecki Helicopter Corp., Morton, Pa.

This paper was sponsored by the ASLE Technical Committee on Lubrication Fundamentals, and presented at the ASLE 9th Annual Meeting, Cincinnati, April 6, 1954.

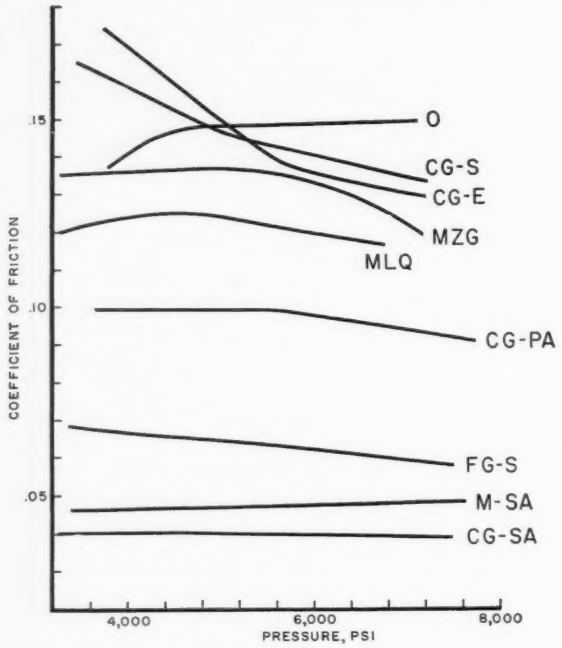

Fig. 2. The coefficient of static friction for dry film lubricants as a function of bearing pressure. Steel rods, heat treated 12% Cr, hardness 22 Rc; Aluminum blocks, 14ST-6, hardness 135 Bhn. Legend: O, no lubrication; CG-S, colloidal gaphite, silicone resin; CG-E, colloidal graphite, epoxy resin; MZG, MoS_2 + $ZnCroO_4$ + gum arabic; MLQ, MoS_2 in laquer; CG-PA, colloidal graphite painted on pin, alcohol dispersion; FG-S, flake graphite, silicone resin; M-SA, MoS_2 sprayed, alcohol dispersion; CG-SA, colloidal graphite sprayed, alcohol dispersion.

accrued. The amount of movement at the surfaces was 160 microinches. Strain gages were used to determine the force exerted by each of the clamping bolts; this was maintained at 15,000 psi during the fretting tests.

The data were obtained by beginning with simple unbonded film lubricants such as molybdenum disulfide and colloidal size graphite. Tests were run to obtain the coefficient of friction of these materials as well as the bare blocks and pins. Vibration tests were then run on these materials and the amount of damage revealed after various test periods was recorded. To obtain material with different coefficients of friction it was necessary to bond the graphite and molybdenum disulfide in various resins. By maintaining the percent of lubricating solids at a fixed value of 35%, a lubricating film could thereby be attained with varying coefficients of friction depending upon the bonding agent. The surface roughness was mainatined at a fixed level of 32 rms microinches through the test program.

DISCUSSION. Before proceeding with the discussion of the fretting test data, it is best to investigate the behavior of the various compounds as shown by the friction tests. Referring to Fig. 2, several characteristics of the virgin coating are apparent. It can be seen that the lowest coefficients of friction were obtained with 100% graphite or 100% molybdenum disulfide materials sprayed from an alcohol dispersion. The effect of the bonding resin addition is to increase the coefficient of friction which is evident on the chart.

It might be also noted that particle size and the form of the lubricant also have a definite effect on the position and appearance of the friction curve. Using the same proportion of lubricating solids to binder ratio with both flake and colloidal graphite has given two supposedly independent curves. This, however, is not a complete picture of the effectiveness of the respective lubricants because of the importance of the binder to surface area of the lubricant ratio.

All of the tests just described are based on the virgin film before it is burnished or disturbed by movement of the assembly. Caution must be observed that the selection of the lubricant should not be on the basis of tests on the virgin film. For example, Fig. 3 shows how these compounds change their friction characteristics when they are subjected to prior movement before testing. The pins used for these tests were rotated about five revolutions under mild pressure and then gave resultant friction characteristics as shown on the graph in dashed lines.

The resultant curves did show signs of becoming horizontal at the higher pressures. To determine what would occur with additional rotation, the epoxy-resin coated pin was rotated an additional five

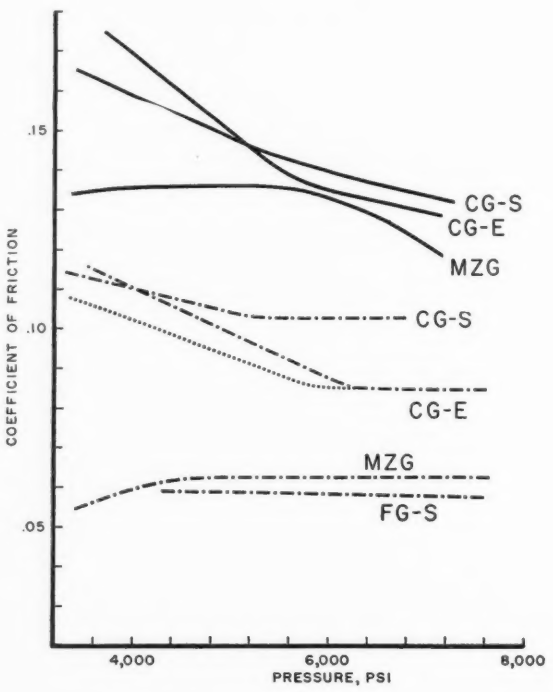

Fig. 3. The effect of prior movement on the coefficient of static friction of dry film lubricants. Rubbing surfaces as in Fig. 2. Legend as in Fig. 2. Solid lines, no prior movement of rubbed surfaces. Dashed lines, pins were rotated under mild pressure before testing. Dotted line, pins were given additional rotation before testing.

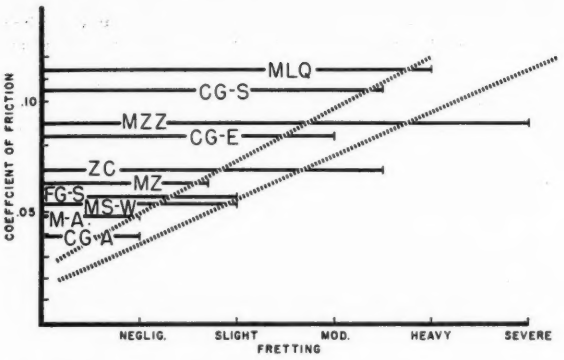

Fig. 4. Qualitative illustration of the degree of fretting as related to the coefficient of friction of the lubricating film. Legend: CG-A, 100% colloidal graphite in alcohol dispersion; M-A, 100% MoS_2 in alcohol dispersion; MS-W, MoS_2 + water paste; FG-S, flake graphite in silicone resin; MZ, MoS_2 + 10% $ZnCrO_4$; ZC, $ZnCrO_4$; CG-E colloidal graphite in epoxy resin; MZZ, MoS_2 + 25% $ZnCrO_4$; CG-S, colloidal graphite in silicon resin; MLQ, MoS_2 in lacquer.

rotations and the resultant curve was as shown by the dotted line. Apparently, the only effect of this additional rotation was to lower the left portion of the curve closer to the horizontal and also to move the transition point to the left. The horizontal portion remains in essentially the same position. Supposedly the effect of additional rotation would be to continue to lower the left portion of the curve while the transition point moved to the left until a constant coefficient is obtained which will then be in agreement with Amonton's law.

The results of the fretting test program are shown in Table I of this report. The variation of the coefficient of friction with bearing load on the materials tested is shown in Figs. 2 & 3. It can be seen from a comparison of the coefficients of friction with the fretting test data that there is some indication that the coefficient of friction is related to the amount of fretting that has taken place. Fig. 4 shows this tendency. It may be noted that the two exceptions to this trend are both compounds containing high percentages of zinc chromate.

Prior tests showed that the resins used would have no abrasive effects and that the only effects that they would have would be to determine the ease of movement of the materials on each other. Since the lubricants would still possess essentially the same properties when bonded to the surface as when free, the different coefficients obtained are assumed to be related to the properties of the different resins used. None of these resins seemed to be able to withstand vibration under pressure when used alone and the ability of the resin-lubricant compound to withstand the large number of cycles before fretting occurred can, therefore, be attributed to the bearing properties of the lubricants.

CONCLUSIONS. From the testing performed it can be concluded that dry film lubricants are effective in delaying the start of fretting corrosion and that the bonding material as well as the lubricating solids must be considered in the selection of lubricants. Under static conditions the colloidal-sized unbonded low-friction base lubricants, graphite and molybdenum disulfide, appear just as effective in preventing the start of fretting as the best of the more complex bonded low-friction materials.

Because of the effect of the variables mentioned earlier in this article, a thorough understanding of the operating conditions involved must be obtained before the most efficient lubricating compound can be selected.

The selection of the proper lubricant can result in the reduction or elimination of fretting corrosion once the operating conditions are known.

Hence if the need is simply for a lubricant with a low coefficient of friction and optimum resistance to fretting, either a 100% colloidal graphite or 100% molybdenum disulfide layer will be most effective. However, if air currents, high centrifugal forces, or other conditions tending to remove lubricant become important, a lubricant containing a binder may be desired. In such a case the most desirable compound

Table I. 12% steel bars in 14 ST-6 aluminum blocks. Order of rating: negligible, slight, moderate, substantial, severe.

Test Type	Coefficient of Friction	Cycles in Millions	Damage
Plain: No compound	0.090	3.2	Slight
		5.0	Negligible
		5.0	Slight
		15.0	Slight
		15.0	Substantial
		15.0	Negligible
Molybdenum Disulphide & Water Paste	0.055	5	Negligible
		5	Negligible
		15	Slight
		15	Slight
Molybdenum Disulphide in Lacquer	0.115	15	Substantial
100% Zinc chromate	0.070	15	Moderate
		15	Substantial
25% Zinc chromate powder	0.090	5.2	Slight
75% Molybdenum Disulphide paint		9	Moderate
		15	Severe
10% Zinc chromate powder	0.062	15	Slight
90% Molybdenum Disulphide Paint		15	Slight
		15	Negligible
100% Molybdenum Disulphide	0.048	15	Negligible
		15	Negligible
Molybdenum Disulphide Molasses Bonded	0.045	15	Slight
		15	Negligible
		15	Negligible
		15	Negligible
Fine Flake Graphite in Silicone Resin	0.058	15	Slight
		15	Slight
100% Colloidal Graphite	0.040	15	Negligible
Colloidal Graphite in Epoxy-Resin	0.085	15	Moderate
Colloidal Graphite in Silicone Resin	0.104	15	Substantial
		15	Moderate

yielding the least sacrifice of the friction coefficient and still excellent fretting resistance of the compositions tested, would be one utilizing a silicone resin and fine flake graphite. Likewise, if a degree of corrosion resistance is desired, the molybdenum disulfide compounds containing ten percent zinc chromate would be most applicable. It can therefore be seen that the type of operating environment must be known to use dry film lubricants most effectively. Without this knowledge the application of a lubricant not suited for the conditions at hand might result in service which does not measure up to the results desired.

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New Products

Constant Temperature Bath. Originally developed for Turbine Oil Oxidation Test ASTM D-943, a new constant temperature bath can also be used for Kinematic Test ASTM D-445, Transformer Oil Oxidation Tests, and all types of constant temperature work requiring temperatures up to 100 C. and sensitivity of control to ± .01 C. Unit consists of a 12" dia. by 18" high Pyrex jar enclosed in stainless steel jacket, with transparent plastic window. Stirrer is induction type with special centrifugal impellor; temperature control utilizes electronic relay pulling only 5 microamperes, and adjustable Roto-Set regulator. Modifications can be made to suit individual requirements. (Bulletin 4148, Labline, Inc., 217 Desplaines, Chicago, Ill.)

Oil-Rite Overflow Sights. Newly developed Overflow Sights, used in oil lines of circulating systems to maintain a constant visible oil level, permit checking of liquid flow and clarity of liquid at a glance. Used mainly on large ring oil or reservoir type bearings of steam turbines or on gear boxes, they can be used on many other applications. Flow of liquid is upward through bottom center inlet overflowing stand pipe, draining through side outlet. Lucite sights are provided. (For applications where the temperature exceeds 160 F., glass sights should be used and can be supplied.) Also available are Lucite top enclosure plate to observe oil flow from elevated point. (Oil-Rite Corp., 2328 Waldo Blvd., Manitowoc, Wisc.)

D-A "Extra-Treated" Diesel Oil. An improved crankcase lubricant, developed especially for certain super-charged diesel engines, has been announced that qualifies as a Caterpillar Superior Lubricant Series Two and has replaced D-A's former qualifications. Utilizing a new type of additive which has increased the detergency reserve approximately three times, the improved product is the result of close cooperation with the engine manufacturers and the chemical additive industry. (D-A Lubricant Co., Indianapolis 23, Ind.)

Aro "Surfa-Chek" Grease Fittings. New cleanliness to safeguard bearings, achieved with ball-in-tip design, heads the list of many new features for improved performance in a new line of "Surfa-Chek" grease fittings. Ball in tip of fitting keeps out dirt and other foreign matter which would otherwise cause damage to bearings; volume flow results from enlarged inner passage which admits more lubricant and helps cut time on important lubrication jobs; a balanced action spring retracts easily to allow maximum lubricant flow under pressure, yet holds ball firmly in sealing position at all other times. Perfect spherical shape of base allows coupler jaws to form leakproof seal, even at a wide angle; exclusive head design with concave shape permits easier disconnection of coupler jaws, which reduces wear on jaws and fittings; all threads are accurately machine-cut for installation ease. (Aro Equipment Corp., Bryan, Ohio.)

Engine Wear Meter. A new engine wear meter has been developed that is attached permanently to any engine and warns the operator when there is fuel dilution, water or antifreeze leakage, running on dead filters, wrong grade make-up oil, and the like. The meter responds to any increase or decrease in viscosity but, unlike previous instruments, does not respond to the normal thickening or thinning of the oil incidental to varying operating tempera-

(Continued on p. 132)

SOME VISCOSITY-SHEAR CHARACTERISTICS OF LUBRICANTS

by E. E. Klaus & M. R. Fenske*

Polymer thickened hydraulic and lubricating oils undergo a loss in viscosity when subjected to high rates of shear as in throttling valves, piston clearances and bearings. The loss in viscosity can be either temporary or permanent depending on the polymer and the duration and severity of the shearing action. This paper summarizes some experimental work on this subject and relates the results to typical parts of hydraulic systems and lubricated mechanisms.

Three linear-type oil-soluble polymers were used in this study: polymethacrylate, polybutene, and polystyrene. Such materials are commonly used in concentrations below about 10 per cent to increase the viscosity and viscosity index of a variety of mineral oils. Depending upon the length of the polymer chain, or its molecular weight, the viscosity of these polymer solutions is affected by the rate of shear and by the intensity and persistence of throttling or turbulence in the oil.

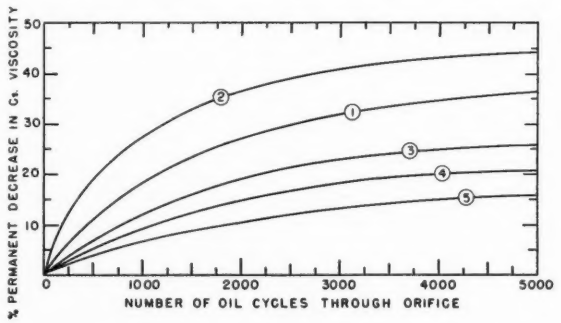

Fig. 1. Permanent shear characteristics of polymer solutions. Test conditions include: test temperature, 100 F.; loading device, sharp edged orifice; and pressure drop across loading device, 1000 psi. Compositions of test fluids shown in Table II. All test fluids prepared with PRL 2857 mineral oil base stock. Key:

Curve No. 1, fluid desig. PRL 3014, type polymer polystyrene.

Curve No. 2, fluid desig. PRL 2914, type polymer polymethacrylate 160.

Curve No. 3, fluid desig. PRL 2923, type polymer polymethacrylate 55.

Curve No. 4, fluid desig. PRL 2924, type polymer polybutene.

Curve No. 5, fluid desig. PRL 2913, type polymer polymethacrylate 25.

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It is common practice to classify the characteristics of fluid flow into two types: laminar and turbulent. In the laminar condition the rate of oil flow is dependent on the first power of viscosity. In the turbulent condition, oil flow is dependent only on the one-tenth to two-tenth power of viscosity.

When oils containing these polymers are subjected to shear rates from about 0.1 to 1.0 million reciprocal seconds in laminar flow, there is a temporary decrease in viscosity. That is, the viscosity decreases as long as the shearing stress is maintained. When the stress is removed, the original viscosity reappears. This laminar flow condition frequently exists when the oil flow and oil passages are small. Leakage past seals, pintles, and through some piston-cylinder wall clearances are of this type.

When these polymer-containing oils undergo intense throttling or turbulence, such as in high pressure jets or in high volume flow orifices and other restrictive passages, the viscosity gradually decreases and it is never recovered.

The extent to which both temporary and permanent viscosity decrease occurs depends on many factors, such as the size of the polymer and its concentration in the oil; the nature, intensity and persistence of the shearing action; the temperature; and the viscosity of the base stock. The two effects are

Table I. Estimated shear rates encountered in lubricant use.

Application	Radial Clearance Between Moving and Stationary Parts, Inches	Relative Velocity of Parts	Approximate Shear Rate, Sec. $^{-1}$
Piston-Cylinder Clearance in Automotive Engine[1]	0.001	200 to 400 Inches Per Sec.	200,000 to 400,000
2 Inch Diameter Plain Journal Bearing[2]	0.001 to 0.0001	1800 r.p.m.	188,000 to 1,880,000
Ball-Type Hydraulic Pump[3]	0.0003	3500 r.p.m.	3,000,000
Bosch Piston-Type Diesel Fuel Pump	0.00004	36 Inches Per Sec.	900,000

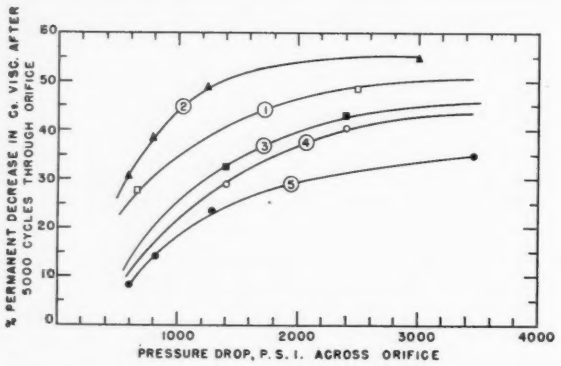

Fig. 2. Effect of pressure drop on permanent viscosity decrease due to shear. Test conditions include: test temperature, 100 F.; and loading device, sharp edged orifice. Composition of test fluids shown in Table II. All test fluids prepared with PRL 2857 base stock. Key: (Same as for Fig. 1).

interrelated in that an oil showing a high temporary loss will usually show a large permanent viscosity decrease, if the throttling condition is severe enough.

Temporary viscosity decrease has been measured experimentally in a capillary-type high-shear viscometer. This is a relative viscometer. Viscosity decrease is based on the relative behavior of polymer solutions and narrow-boiling range mineral oil fractions under the same test conditions. The mineral oil fractions are considered to be Newtonian.

In addition to data showing the fundamental nature and extent of these two properties, examples are given illustrating how these effects occur in practice. In one case leakage past pintles and through piston-cylinder clearances is illustrated to show the temporary decrease effect. The behavior of various hydraulic pumps of both the gear and piston types, demonstrates the nature of the permanent viscosity change. Tables and Figures give the details of this study.

APPARATUS. Briefly, the equipment used in studying the changes in viscosity of oils containing linear type polymeric additives comprises a piston pump capable of generating pressures to about 3,000 psi, and means for dropping this pressure by flow through calibrated capillary tubes or orifices. Other equipment measures pressure drop, flow rate, and temperature. Capillary tubes are used to confine the

Table II. Properties of polymer solutions. All fluids prepared to 33.0±0.2 centistokes viscosity at 100 F. in PRL 2857 mineral oil base stock (8.8 centistokes at 100 F.). Key: (1) Values given for relative molecular weight are the censtoke viscosities at 210 F. for blends of 30 weight per cent active polymer in a gas oil of about 3.5 centistokes viscosity at 100 F.

Fluid Designation	Polymer			CS. Visc. at 100°F.	A.S.T.M. Slope 210° to 100°F.	% Temporary Visc. Decrease at		% Permanent Visc. Decrease after 5000 Cycles Through Orifice at	
	Type	Rel. Mol.(1) Wt.	Wt.%			100,000 Sec.$^{-1}$	1,000,000 Sec.$^{-1}$	1000 P.S.I.(ΔP)	3000 P.S.I.(ΔP)
PRL 2857	-	-	-	8.82	0.842				
PRL 2856	-	-	-	33.1	0.754				
PRL 2913	Polymethacrylate	25	10.2	33.0	0.539	11	30	18	34
PRL 2923	Polymethacrylate	55	7.6	32.8	0.525	15	40	29	38
PRL 2914	Polymethacrylate	160	4.7	33.2	0.505	24	47	44	55
PRL 2924	Polybutene	315	4.4	33.1	0.589	13	31	21	42
PRL 3014	Polystyrene	335	4.3	33.1	0.524	26	43	36(Est.)	49(Est.)

Table III. Viscosity temperature characteristics of polymer solutions. All polymer blends prepared in PRL 2857 mineral oil base stock.

Fluid Designation	Polymer			Viscosity in Cs. at		Viscosity Index (A.S.T.M.)	A.S.T.M. Slope (210° to 100°F.)	Rate of Change in Visc. With Temp. (Cs. per °F.)	
	Type	Conc., Wt. %	Rel. Mol. Wt.	210°F.	100°F.			at 210°F.	at 0°F.
PRL 2857	None	-	-	2.25	8.82	60	0.842	0.019	8.8
PRL 2856	None	-	-	5.32	33.1	102	0.754	0.061	109
PRL 2913	Polymethacrylate	10.2	25	8.03	33.0	168	0.539	0.073	14.4
PRL 2923	Polymethacrylate	7.6	55	8.24	32.8	170	0.525	0.073	12.6
PRL 2914	Polymethacrylate	4.7	160	8.65	33.2	172	0.505	0.081	11.0
PRL 2924	Polybutene	4.4	315	7.28	33.1	161	0.589	0.072	22.8
PRL 3014	Polystyrene	4.3	335	8.31	33.1	170	0.524	0.078	12.8

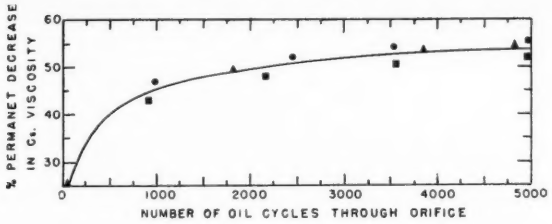

Fig. 3. Effect of temperature level on permanent viscosity decrease due to shear. Test conditions include: loading device, sharp edged orifice; and pressure drop across the loading device, 2100 psi. Key:

▲, test fluid PRL 2914; conc. of polymethacrylate 160, wt. %, 4.7; base stock visc. at test temp., Cs, 8.8; blend visc. at test temp., Cs, 33.1; test temp., F., 100.

■, test fluid PRL 2914; conc. of polymethacrylate 160, wt. %, 4.7; base stock visc, at test temp., Cs, 2.2; blend visc. at test temp., Cs, 9.50 test temp., F., 200.

●, test fluid PRL 3438, conc. of polymethacrylate 160, wt. %, 4.7; base stock visc. at test temp., Cs, 2.2; blend visc. at test temp., Cs, 9.74; test temp., F., 100.

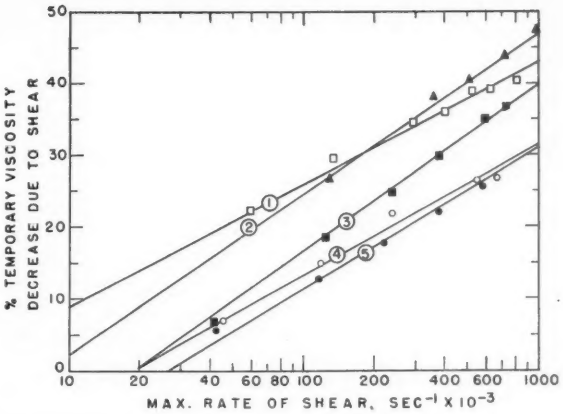

Fig. 4. Temporary viscosity-shear characteristics of polymer solutions. Compositions of test fluids shown on Table II. All test fluids prepared with PRL 2857 mineral oil base stock. Tests conducted at 100 F. capillary inlet temperature in the PRL high shear viscometer. Key: (Same as for Fig. 1).

flow to the laminar or streamline region, while orifices are used to produce excessive turbulence and throttling. The apparatus has been described previously[4].

SHEAR SEVERITY. Until the use of additives to improve the viscosity index of oils became common, most fluid lubricants were Newtonian, i.e., their viscosity under operating conditions was not significantly affected by shear rate, even though most mechanical equipment using such lubricants produced considerable shearing stresses on the sliding or rotating parts. Typical rates of shear are illustrated in Table I. It is evident that when the viscosity of a lubricant becomes a function of shear rate, new concepts and problems in lubrication may

Table IV. The effect of discharge pressure on the shear severity of a sharp edged orifice. In cases where the system is loaded by an orifice and a low shear coil, the coil is inserted in the line after the orifice to increase discharge pressure for the orifice. The low shear coil does not contribute significantly to the permanent viscosity decrease. Key: (1) Pressure drop across the orifice; (2) Discharge pressure for orifice.

Fluid Designation	Overall Viscosity, CS. at 100°F.	Base Stock Viscosity, CS. at 100°F.	Polymer Type	Polymer Conc., %	Polymer Relative Molecular Wt.	Pressure Loading Device	Total Press., P.S.I.	$\Delta P'$,(1) P.S.I.	P'',(2) P.S.I.	5000 Cycle CS. Viscosity Decrease, %
PRL 3202	15.3	3.5	Polymethacrylate	11.5	25	Orifice	900	850	50	16
						Orifice	1700	1650	50	29
						Orifice	2350	2300	50	33
						Orifice + low shear coil	2650	2300	350	26
						Orifice + low shear coil	2650	2075	575	16
						Orifice + low shear coil	2675	1875	800	16
PRL 3115	14.3	3.5	Polymethacrylate	7.5	55	Orifice	500	450	50	7
						Orifice	2150	2100	50	38
						Orifice	2700	2650	50	38
						Orifice + low shear coil	2650	2275	375	33
						Orifice + low shear coil	2700	2275	425	29
						Orifice + low shear coil	3050	2500	550	16
						Orifice + low shear coil	3050	2100	950	7
PRL 3190	14.7	3.5	Polymethacrylate	5.2	160	Orifice	350	300	50	26
						Orifice	1525	1475	50	52
						Orifice	1950	1900	50	54
						Orifice + low shear coil	1550	1500	50	51
						Orifice + low shear coil	2400	1900	500	42
						Orifice + low shear coil	2375	1625	750	40
						Orifice + low shear coil	2700	1475	1225	26
PRL 3185	14.0	3.5	Polybutene	4.5	315	Orifice	850	800	50	21
						Orifice	1700	1650	50	36
						Orifice	2325	2275	50	40
						Orifice + low shear coil	2600	2275	325	29
						Orifice + low shear coil	2650	2150	500	24
						Orifice + low shear coil	2650	1725	925	21

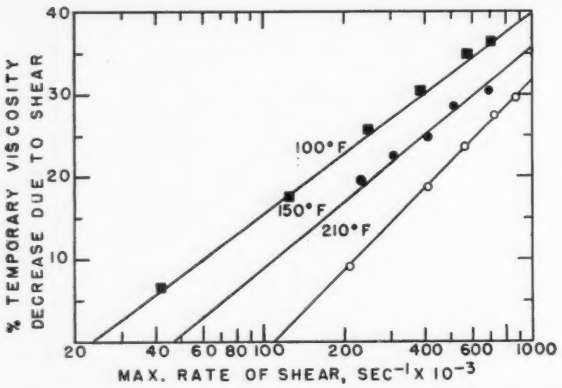

Fig. 5. Effect of temperature level on temporary viscosity decrease due to shear. Test fluid PRL 2923=7.6 weight per cent polymethacrylate 55 in PRL 2857 mineral oil base stock. Tests conducted at indicated capillary inlet temperatures in the PRL high shear viscometer.

arise. This paper illustrates the effects of shear on the viscosity of certain types of polymer-containing oils. In this discussion shear will be used to denote a stress on oil films either in streamline or turbulent flow.

TYPES OF POLYMERS. While there are many linear type polymers that can be dissolved in oils to improve their viscosity and viscosity-temperature properties, this study relates to three: polymethacrylate, polybutene, and polystyrene. All are commercially available and are used for blending in oils.

Some properties of mineral oil solutions of these three polymers are listed in Table II. It is evident that these polymers, in 3 to 10% concentrations in an oil, impart considerable viscosity to the oil and lower its viscosity-temperature coefficient, as shown by A.S.T.M. slope. It is also clear that, depending on the relative molecular weight of the polymer, there is considerable temporary as well as permanent loss in viscosity under certain types of shearing conditions. It is the purpose of this paper to delineate several aspects of this shearing phenomenon.

Viscosity index (V.I.), like A.S.T.M. slope, is a common means for expressing the viscosity-temperature characteristics of oils. Where the lubricant is to be used over wide temperatures, such as in automotive and aircraft equipment, high viscosity index oils are desired. About the highest V.I. values obtainable in mineral oils by refining are 100 to 120.

It is evident from Table III that V.I. levels much above those otherwise available are readily obtained merely by dissolving in the oil a selected linear type polymer.

The data in Table III on rate of change of viscosity with temperature at 210 F. and at O F. are noteworthy. If only a low rate of viscosity change with temperature is desired, a low viscosity fluid is the way to get it. However, if both high viscosity and high V.I. are desired, then the polymeric additive route is the direction to take. This is seen by comparing the rates of viscosity change at O F. in Table III.

PERMANENT VISCOSITY LOSS. Fig. 1 shows the permanent loss in viscosity of these polymer blended oils. To get this effect the oil is simply pumped to a high pressure (such as 1,000 psi.) and then this pressure is released suddenly by flow through an orifice. The oil is circulated many times, and finally an asymptotic value of viscosity loss is obtained for the particular throttling conditions used. If more stringent conditions are used, such as a greater pressure drop over the orifice, then there is a greater permanent viscosity loss. This is shown in Fig. 2.

Fig. 3 shows that temperature per se is not an important factor affecting permanent viscosity loss.

EFFECT OF DISCHARGE PRESSURE. It has been found that the back pressure on an orifice, or throttling valve, affects considerably the magnitude of the permanent viscosity loss induced in a fluid. This is of some practical significance in the design of throttling or pressure unloading devices to be used with polymer-containing oils. Illustrative data are presented in Table IV for 100 F. A low shear coil, or a tube in which the fluid flows in

Table V. Effect of polymer molecular weight and concentration on temporary and permanent viscosity decrease due to shear. All tests conducted with the indicated concentration of polymethacrylate in PRL 2857 mineral oil base stock. The two polymers used differ only in relative molecular weight.

Test Fluids	PRL 2913	PRL 2914	PRL 3041
Rel. Mol. Wt. of Polymethacrylate	25	160	160
Conc. of Polymethacrylate, Wt. %	10.2	4.7	10.2
Viscosity of blend in centistokes at 210°F.	7.94	8.41	22.6
at 100°F.	32.7	32.5	85.1
A.S.T.M. slope 210° to 100°F.	0.542	0.512	0.382
Effective viscosity at 100°F.			
and 100,000 Sec.$^{-1}$	28.9	24.6	48.5
500,000 Sec.$^{-1}$	24.8	19.4	31.9
1,000,000 Sec.$^{-1}$	22.9	17.2	24.6
% Temporary decrease in overall viscosity at 100°F.			
and 100,000 Sec.$^{-1}$	12	25	43
500,000 Sec.$^{-1}$	24	40	63
1,000,000 Sec.$^{-1}$	30	47	71
% Temporary decrease in viscosity due to polymer			
at 100°F. and 100,000 Sec.$^{-1}$	16	34	48
500,000 Sec.$^{-1}$	33	55	70
1,000,000 Sec.$^{-1}$	41	65	79
% Permanent decrease in overall viscosity at 100°F.			
and 1000 P.S.I. (ΔP)	18	44	-
3000 P.S.I. (ΔP)	34	55	73
% Permanent decrease in viscosity due to polymer			
at 100°F. and 1000 P.S.I. (ΔP)	25	60	-
3000 P.S.I. (ΔP)	46	75	82
Final viscosity after permanent decrease in overall viscosity at 100°F.			
and 1000 P.S.I. (ΔP)	26.8	18.2	-
3000 P.S.I. (ΔP)	21.6	14.7	22.7

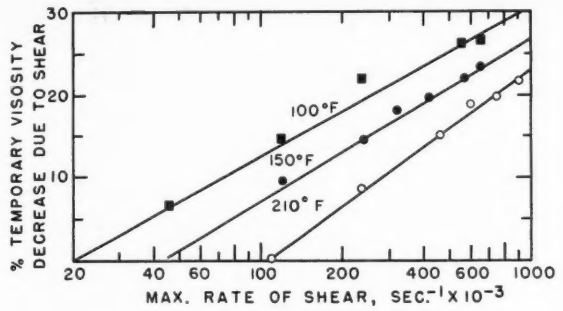

Fig. 6. Effect of temperature level on temporary viscosity decrease due to shear. Test fluid PRL 2924=4.4 weight per cent polybutene in PRL 2857 mineral oil base stock. Tests conducted at indicated capillary inlet temperatures in the PRL high shear viscometer.

streamline flow, does not produce any appreciable permanent viscosity loss. It takes devices creating large amounts of turbulence, or wire-drawing, to produce permanent viscosity loss. It is evident from this Table that the same pressure drop across an orifice can produce two different values of viscosity loss, and that the higher the back pressure on the orifice, for the same orifice pressure drop, the less the viscosity loss.

TEMPORARY VISCOSITY LOSS. When polymer-containing fluids are sheared in streamline flow there is little or no permanent viscosity loss. However, there is a temporary viscosity loss, i.e. the fluid while flowing in streamline flow at high shear rates has a lower viscosity than when flowing at low shear rates at the same temperature. This process is reversible in that the removal of the shearing stress causes the viscosity of the fluid to revert to the value it had before the stress was applied. This is true as long as there is no device in the system causing permanent viscosity loss.

A simple way to observe this effect is to pass the fluid, while in streamline flow, through a capillary tube which has been previously calibrated as a viscometer using Newtonian liquids. It will be found that the polymer-containing fluid flows through the capillary easier than it should. That is, for the same flow rate less pressure is needed to maintain this flow than if the fluid were Newtonian.

Illustrative data are given in Figs. 4, 5, and 6. It is seen that a certain shear rate is required to initiate this effect; that the higher the molecular weight of the polymer, the easier it is to induce this viscosity loss; and that the higher the temperature, the less is the effect. Fig. 7 presents data on the latter point.

POLYMER EFFECTS. Instead of studying the viscosity properties of the overall fluid, they can be studied in terms of the viscosity effects due to the polymer. Nothing happens to the base stock during shear; the changes are due to the polymer. In

Table VI. Effect of permanent viscosity decrease on blending efficiency and temporary viscosity decrease due to shear. Composition of test fluids shown on Table II. All test fluids prepared with PRL 2857 mineral oil base stock.

Test Fluid	PRL 2913	PRL 2923	PRL 2914	PRL 2924	PRL 3014
Properties before permanent shear test					
Viscosity in centistokes at 210°F.	7.94	8.24	8.41	7.15	7.98
100°F.	32.7	82.8	32.5	32.6	32.0
A.S.T.M. slope 210° to 100°F.	0.542	0.525	0.512	0.593	0.532
Effective viscosity at 100°F. and					
100,000 Sec.$^{-1}$	28.9	27.7	24.6	28.4	23.8
500,000 Sec.$^{-1}$	24.8	22.2	19.4	24.4	19.9
1,000,000 Sec.$^{-1}$	22.9	19.7	17.2	22.6	18.3
% Temporary decrease in overall viscosity at 100°F.					
and 100,000 Sec.$^{-1}$	12	16	25	13	26
500,000 Sec.$^{-1}$	24	33	40	25	38
1,000,000 Sec.$^{-1}$	30	40	47	31	43
% Temporary decrease in viscosity due to the polymer					
at 100°F. and 100,000 Sec.$^{-1}$	16	21	34	18	35
500,000 Sec.$^{-1}$	33	40	55	34	52
1,000,000 Sec.$^{-1}$	41	55	65	42	59
Properties after permanent viscosity decrease due to shear					
% Viscosity decrease due to shear	16	20	39	22	28
Viscosity in centistokes at 210°F.	6.66	6.42	4.72	5.59	5.43
100°F.	27.6	25.8	18.5	24.9	21.7
A.S.T.M. slope 210° to 100°F.	0.575	0.572	0.627	0.634	0.604
Effective viscosity at 100°F. and					
100,000 Sec.$^{-1}$	26.2	24.5	18.0	24.1	20.0
500,000 Sec.$^{-1}$	23.5	20.7	15.9	21.6	18.5
1,000,000 Sec.$^{-1}$	22.4	19.1	15.1	20.5	17.8
% Temporary decrease in overall viscosity at 100°F.					
and 100,000 Sec.$^{-1}$	5	5	3	3	8
500,000 Sec.$^{-1}$	15	20	14	14	15
1,000,000 Sec.$^{-1}$	19	26	19	18	18
% Temporary decrease in viscosity due to the polymer					
at 100°F. and 100,000 Sec.$^{-1}$	7	8	5	5	13
500,000 Sec.$^{-1}$	22	30	29	21	25
1,000,000 Sec.$^{-1}$	28	39	35	27	30

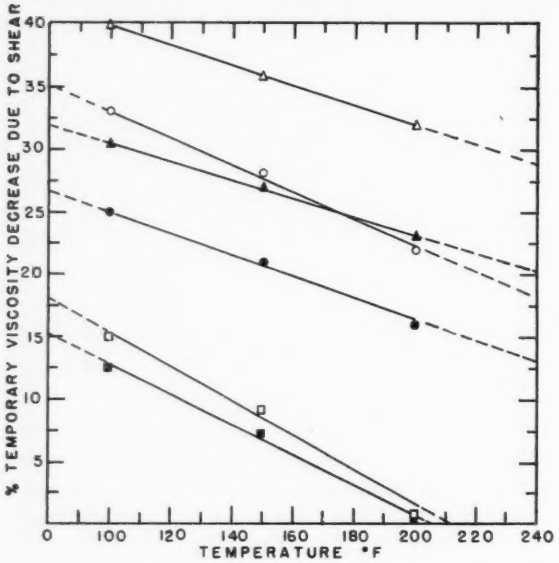

Fig. 7. Effect of temperature on the temporary viscosity decrease due to shear. Compositions of test fluids shown on Table II. All test fluids prepared with PRL 2857 mineral oil base stock. Tests conducted at the indicated temperatures and shear rates in the PRL high shear viscometer. Shear rates:

▲ △ = 1,000,000 Sec.$^{-1}$
● ○ = 500,000 Sec.$^{-1}$
■ □ = 100,000 Sec.$^{-1}$
△ ○ □ = Polymethacrylate (PRL 2923)
▲ ● ■ = Polybutene (PRL 2924)

Tables V, VI, and VII two values of viscosity loss are reported. In one case the loss is given as the per cent of the original viscosity of the fluid that is lost, or absent, in the final fluid. In the other case the per cent viscosity decrease is based on that part of the fluid's viscosity that is due to the polymer, and the value is expressed as a loss in the thickening power of the polymer.

Table V shows that, if high molecular weight polymers are used (such as in oil PRL 3041), the bulk of the viscosity properties originally imparted to the oil by the polymer can be depleted. This means that the polymer's molecular weight should be tailored to the duty placed on the blended oil. When excessive turbulent shearing effects are present, and if viscosity retention is desired, the lower molecular weight polymers are preferred. On the other hand, if the fluid is largely in streamline flow, the use of larger polymers to get temporary viscosity loss may be advantageous in reducing friction when liquid layers are in viscous shear.

It is believed that the time necessary to orient the polymer molecules from a random condition in a quiescent liquid to a state where the polymer's long axis is aligned in the direction of flow ranges between 10^{-2} and 10^{-5} seconds. This orientation and alignment is responsible for the temporary viscosity loss.

This orientation and alignment can have practical application. For example, in a journal bearing a polymer-thickened oil can show less friction than a Newtonian oil of the same low shear viscosity. Furthermore, the eccentricity of the shaft under load in the bearing can be nearly the same as with the Newtonian oil. This means that the oil film thickness can be about the same, and yet friction is lower because of the lowering in viscosity by shear at the point of minimum clearance in the loaded bearing.

COMBINED EFFECTS. Table VI illustrates what happens to polymer-containing oils before and after being subjected to high shear in turbulent flow. It is evident that if the oil has been permanently lowered in viscosity by shear, it also shows less temporary viscosity loss. Thus these two viscosity effects are interrelated, and they are not the same for all polymers. Some types may show somewhat greater resistance to permanent viscosity loss for the same temporary viscosity changes.

EFFECT OF BASE STOCK. Table VII shows that these temporary viscosity changes in polymer solutions are not a critical function of the viscosity of the oil in which they are dissolved. Here again the loss in viscosity is expressed in terms of the overall fluid as well as a loss in the thickening power of the polymer. About the same temporary

Table VII. Effect of base stock viscosity on temporary viscosity decrease due to shear. Base stocks are mineral oil fractions of the indicated viscosity levels. Fluids containing the same polymethacrylate are matched in polymer concentration in base stocks of different viscosity levels.

Test Fluids	PRL 2923	PRL 2286	PRL 2914	PRL 2946
Relative Mol. Wt. of Polymethacrylate	55	55	160	160
Concentration of Polymethacrylate, Wt.%	7.6	7.5	4.7	5.2
Viscosity of base stock in centistokes at 100°F.	8.8	3.5	8.8	4.2
Viscosity of blend in centistokes at 210°F	8.24	5.16	7.94	5.91
at 100°F.	32.8	14.3	32.7	15.9
A.S.T.M. slope of blend (210° to 100°F.)	0.525	0.479	0.512	0.446
Effective viscosity in centistokes at 100°F.				
and 100,000 Sec.$^{-1}$	27.7	12.2	24.6	13.5
500,000 Sec.$^{-1}$	22.2	10.4	19.4	10.0
1,000,000 Sec.$^{-1}$	19.7	9.1	17.2	8.6
% Temporary decrease in overall viscosity at 100°F.				
and 100,000 Sec.$^{-1}$	16	15	25	15
500,000 Sec.$^{-1}$	33	27	40	37
1,000,000 Sec.$^{-1}$	40	37	47	46
% Temporary decrease in viscosity due to the polymer at				
100,000 Sec.$^{-1}$	21	19	33	21
500,000 Sec.$^{-1}$	40	36	55	50
1,000,000 Sec.$^{-1}$	55	48	65	62

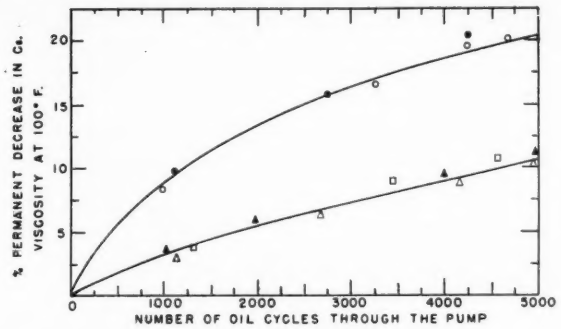

Fig. 8. Shear severity of some Vickers model PF17-3911-10ZE-L hydraulic pumps. Test conditions include: test temperature, 100 F.; test pressure, 2900 psi; pump speed, 3600 rpm; test fluid, typical Spec. MIL-0-5606 fluid; and loading device, low shear coil in which the permanent viscosity decrease due to shear is negligible. Key:

□ , No. 1 pump with new valve plate used.

△▲, No. 2 pump with new valve plate used.

○●, No. 2 pump with old valve plate used.

viscosity loss occurs in each oil, and this effect is similar for the two polymer molecular weights shown. Less of the larger polymer is used to attain a certain degree of thickening, but its viscosity loss effects are greater than for the smaller polymer. Thus from a practical standpoint, the cost of blending an oil has to be balanced against its end use.

Changing the chemical composition of the base stock radically does not alter these peculiar viscosity effects due to the presence of polymers. Table VIII shows they exist to essentially the same degree in both an ester and a hydrocarbon base stock when the viscosity properties are matched.

Table VIII. Effect of base stock type on temporary viscosity decrease due to shear.

Test Fluids	PRL 2914	PRL 3012
Rel. Molecular Wt. of Polymethacrylate	160	160
Concentration of Polymethacrylate, Wt.%	4.7	5.3
Base Stock Type	Mineral Oil	Di-sec-Amyl Sebacate
Viscosity of Base Stock in Centistokes		
at 210°F.	2.24	2.30
at 100°F.	8.75	7.58
Viscosity of Blend in Centistokes		
at 210°F.	8.41	9.43
at 100°F.	32.5	31.0
A.S.T.M. Slope of Blend (210° to 100°F.)	0.512	0.446
Effective Viscosity in Centistokes at 100°F.		
and 100,000 Sec.$^{-1}$	25	23
500,000 Sec.$^{-1}$	19	18
1,000,000 Sec.$^{-1}$	17	16
% Temporary Decrease in Overall Viscosity at 100°F.		
and 100,000 Sec.$^{-1}$	25	26
500,000 Sec.$^{-1}$	40	42
1,000,000 Sec.$^{-1}$	47	48
% Temporary Decrease in Viscosity due to polymer at 100°F.		
and 100,000 Sec.$^{-1}$	33	35
500,000 Sec.$^{-1}$	55	56
1,000,000 Sec.$^{-1}$	65	64

PRACTICAL APPLICATIONS. While the foregoing discussion may be viewed as being somewhat academic, these viscosity changes have a certain practical significance. Some of these polymers are used to make special, all purpose, all weather oils for the Armed Services. Specification oils containing these polymers are listed in the first column of Table IX. This Table shows that leakage through close clearance parts, such as around pintles or between pistons and cylinder walls in hydraulic pumps, can be greater than if the oil were completely Newtonian. This is due to the temporary viscosity loss, i.e. a polymer-containing oil can flow more readily than a Newtonian fluid through close clearance parts. The magnitude of this effect can be reduced or enhanced by the selection of the polymer's molecular weight and the base oil used in making the finished blend.

It has been found that a Bosch Diesel fuel pump, even though reciprocating at 1150 r.p.m., can show differences between these polymer-blended oils and Newtonian fluids. In work in this Laboratory the leakage into the crankcase of the pump has been found to be directly proportional to the fluid's high shear viscosity. This shows that even though the piston is reciprocating rapidly in its cylinder, the flow characteristics in the annulus between the piston and cylinder walls are such that these oil layers are in streamline, rather than turbulent flow, resulting in temporary viscosity loss when the oil contains a linear type of polymer. Since flow rate in streamline or laminar flow is dependent on the first power of viscosity, it is evident that temporary changes in viscosity due to shear can be noticed readily in the leakage values.

HYDRAULIC PUMPS. High pressure hydraulic pumps, depending upon their design, produce different shearing actions on the fluid passing through the pump. From a strictly mechanical viewpoint it is difficult to evaluate the magnitude of all

Table IX. Leakage past pistons in hydraulic pumps. Key:

(1) Type 2003 industrial pump at 3600 rpm. Leakage is across pintle seal and through piston-cylinder wall clearance.

(2) Diesel fuel injection pump, type APE3B-100, at 1150 rpm. Leakage is through piston-cylinder wall clearance.

(3) Determined by comparison with the viscosity of a Newtonian mineral oil showing the same leakage rate.

(4) This is the shear rate that would produce the indicated viscosity decrease.

Hydraulic Oil	Pump	Press. Drop Over Leakage Path, p.s.i.	C'stokes Visc. at Test Temp.	Apparent % Visc. Decrease by Shear(3)	Sec.$^{-1}$ Shear Rate(4)
Spec. 51-F-21 (Ord)	Vickers(1)	600	22	18	80,000
	Vickers	1200	22	27	170,000
Spec. 51-F-21	Bosch(2)	1500	28	43	500,000
Spec. MIL-0-5606	Bosch	1500	14	32	500,000

Table X. Shear severity of hydraulic pumps. Test conditions include: test temperature, 100 F.; test fluid, typical Spec. MIL-0-5606 hydraulic fluid; loading device, low shear coil consisting of 1/8 or 1/16-inch diameter copper tubing in which the permanent viscosity decrease due to shear is negligible. Key: (1) Some fluid passes through the by-pass valve on each stroke even at maximum delivery; (2) Indicates the per cent of maximum delivery.

Type Pump	Type Discharge Valves	Pump Speed, R.P.M.	Pressure, P.S.I.	Flow Rate, G.P.M.	% Permanent Viscosity Decrease After 5000 Cycles
Pesco Model 349 gear pump	None	3600	1060 2950	3.4 3.3	10 17
Vickers Model PF17-3911-10ZE-L (old type valve plate) 9 cylinder axial piston pump	Mechanically timed	3600	1075 2900	3.2 3.1	4 21
Vickers Model PF17-3911-10ZE-L (new type valve plate) 9 cylinder axial piston pump	Mechanically timed	3600	2900	3.1	11
Dowty Live-Line Model 1301B.1 7 cylinder radial piston pump	Mechanically timed	3600	875 2500	4.2 4.1	5 14
Bosch variable delivery Diesel fuel injection pump (type APE3B-100 piston pump)	Poppet discharge[1] valve and mechanically timed by-pass valve	1800	1000 1000 2600 2600	0.28 (100%)[2] 0.13 (52%)[2] 0.26 (100%)[2] 0.17 (65%)[2]	4 9 10 14
PRL homogenizer (3 piston Mills Homogenizer)	Poppet	125	2500	1.1	5
Hycon Model 67 (9 cylinder axial piston pump)	Poppet	3600	1350 2350	4.8 4.8	4 5
Hycon Model 67A-050 (5 cylinder axial piston pump)	Poppet	3600	1000 2950	0.7 0.5	2 6

these shearing and throttling effects. When excessive or uncontrolled, they can lead to mal-functioning of the pumps, erosion, vibration, and noise.

Polymer-containing oils can provide the means of procuring an overall integration of these internal shearing effects in pumps. This is illustrated in Table X. The pumps have been loaded with a long capillary tube in which permanent shearing effects are negligible. It is evident that MIL-0-5606 oil, which is a polymer-containing hydraulic oil used by the Air Force in aircraft hydraulic equipment, is a suitable fluid for studying these shearing effects in pumps. Its permanent viscosity loss is indicative of the throttling effects in the pumps.

Fig. 8 is illustrative of how MIL-0-5606 oil can be used to make improvements in pump design. In this case a new design of valve plate has been incorporated into this Vickers pump so that the pump is quieter and runs with less vibration. The behavior of the old and new valve plates, when operating on MIL-0-5606 oil, shows that the new design produces less fluid shear. Doubtless this is why there is less noise and vibration.

In typical service usage the permanent viscosity loss in polymer-containing oils can be kept low and is no cause for concern if the oil and polymer are properly selected and blended. A great deal can be accomplished by tailoring the oil to fit the end use. This is illustrated by Table XI. MIL-0-5606 oil has been used successfully since 1940 in military aircraft hydraulic systems. However, when used in a special hydraulic device, known as a constant speed alternator drive for operating high frequency electrical generators, this oil was found deficient in shear stability. Another oil, MIL-L-6387, was then developed to have the required properties in every respect.

Table XI. Permanent viscosity decrease due to shear in hydraulic applications. Key: (1) Based on evaluation of 34 used samples; (2) Based on evaluation of 30 used samples.

Fluid Type	Application	Service Time, Hours	Per Cent Viscosity Decrease Due to Shear
Spec. MIL-0-5606	3000 p.s.i. Aircraft Hydraulic System (C54 Aircraft)[1]	50 to 1000	5 to 14
Spec. MIL-0-5606	World war II Bomber and Pursuit Aircraft[2]	10 to 900	5 to 10
Spec. MIL-0-5606	Constant Speed Alternator Drive	50 200	38 45
Spec. MIL-L-6387	Constant Speed Alternator Drive	50 200 300	11 12 14

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[1]C. W. Georgi; Motor Oils & Engine Lubrication. Reinhold Publishing Co., N. Y., 1950.
[2]M. H. Arveson. Ind. Eng. Chem. 24, 1932, p. 71.
[3]Private communication, General Electric Co., 1952.
[4]M. R. Fenske, E. E. Klaus & R. W. Dannenbrink. ASTM Special Technical Publication No. 111, 1951, p. 3.

Section News

BALTIMORE, February. D. G. Faust, C. A. Norgren Co., presented a paper entitled "Micro-Fog Lubrication of Machine Tools," emphasizing the practical aspects of applying this technique, with discussion of the fundamental considerations in the design and development of a Micro-Fog lubricating system for existing machine tools, as well as for newly developed machine tools.

March. S. M. Weckstein, The Timken Roller Bearing Co., presented a paper entitled "Anti-Friction Bearing Lubrication." (Submitted by J. E. Buchanan, Sec'y.)

BOSTON, February. J. C. Geniesse, The Atlantic Refining Co., presented a paper entitled "Automotive Lubrication." (Submitted by E. B. Harvey, Jr., Sec'y.)

BUFFALO, January. Lubrication Quiz Panel.

February. Dr. C. R. Austin, Meehanite Metal Corp., presented a paper entitled "Meehanite Metal in Engineering Service," dealing with the significance of the properties of Meehanite metal in regard to materials selection, with special emphasis on items of interest to the lubrication engineer.

March. Tour of the Atlas Refinery of the Socony-Vacuum Oil Co., followed by a paper entitled "Punch Press Lubrication," presented by F. W. Zapf, Verson Allsteel Press Co. (Submitted by L. E. Locke, Jr., Sec'y.)

CHICAGO, January. A. B. Myler, Sun Oil Co., presented a paper entitled "The Theory & Application of Cutting Oils," covering the recent developments in compounding cutting oils with regard to the functional use of the additives involved.

February. Ladies Night, with Mrs. Grace Stiles speaking on "Galena & The Old Galena Trail." (Submitted by A. B. Wilder, Sec'y-Treas.)

FORT WAYNE, February. Tour of the Salisbury Axle Works of Dana Corp., followed by L. Frew, Shell Oil Co., explaining a quick method called "On the Spot Testing" for oil analysis of automotive oils. (Submitted by J. W. Buckner, Program Chrmn.)

MILWAUKEE, January. Panel Discussion on "Centralized Lubrication," with H. Hofmeister, Socony-Vacuum Oil Co., Inc., acting as Monitor; Panelists included representatives from the following companies: Alemite Co., The Farval Corp., Lincoln Engineering Co., Trabon Engineering Corp., Ladish Co., Giddings & Lewis Co., and Pate Oil Co. (Submitted by J. A. Gramling, Sec'y.)

N. CALIFORNIA, January. T. P. Sands (Co-author, J. L. Werner), Monsanto Chemical Co., presented a paper entitled "The Development of Automotive Gear Lubricants — Present & Future," in which the development of the Hypoid Gear was traced showing the reasons for its widespread acceptance for automotive final drives.

February. I. M. Harlow, Tide Water Associated Oil Co., spoke on the subject "Technical Field Service—The Art of Getting 'Just the Facts, Ma'am'," covering experiences in Technical Field Service relating to the application of petroleum products. (Submitted by G. H. Hommer, Reporter.)

PHILADELPHIA, September '54. C. L. Pope, Eastman Kodak Co., presented a paper entitled "Aspects of Lubrication Engineering for Management Consideration," followed by T. G. Roehner (ASLE Regional Eastern Vice-President), Socony-Vacuum Oil Co., Inc., who explained the functions of the ASLE National Technical Committees.

November '54. (Regular meeting) R. O. Braendle, E. I. duPont deNemours & Co., Inc., presented a paper entitled "Inorganic Grease Thickeners." (Joint ASLE-ASME meeting) J. R. Hemeon, General Motors Corp., spoke on the subject "Fire-Resistant Fluids in Hydraulic Equipment."

January. L. D. Cobb, New Departure Div., GMC, presented a paper entitled "Sealed Bearings, Their Design, Function & Limitations."

February. Lubrication Course held at The Franklin Institute, with speakers and their subjects as follows: Dr. H. E. Mahncke, Westinghouse Research Laboratories, "Principles of Lubrication;" R. C. Gunther, Socony-Vacuum Oil Co., & C. R. Gillette, New Departure Div., GMC, "Bearings;" C. A. Bailey, U. S. Steel Corp., "Lubricant Tests;" A. E. Cichelli, Bethlehem Steel Corp.," Lubricant Application and Maintenance of Lubrication Systems;" C. Stone, Esso Standard Oil Co., "Cylinder Lubrication;" C. R. Schmitt, E. F. Houghton & Co., "Hydraulic Fluids;" J. Critchlow, Gulf Oil Corp., "Gear Lubrication;" K. S. Smiley, E. I. duPont deNemours & Co., Inc., "Program of Industrial Plant Lubrication." (Submitted by R. W. Clark, Sec'y.)

PITTSBURGH, January. J. H. Hitchcock, Morgan Construction Co., presented a paper entitled "Oil Film Bearings for Roll Necks," reviewing the history and development of oil film bearings, and discussing the advantages of these bearings from the standpoint of lower power consumption, decreased maintenance, ease and scope of operation. (Submitted by D. W. Howard, Publicity Chrmn.)

TWIN CITIES, January. Dr. W. E. Campbell (ASLE Past President), Brush Laboratories Co., Div. of Clevite Corp., presented a paper entitled "Diagnosis of Lubrication & Wear Problems," covering the latest in micro-technics and inspections, and demonstrating the new micro-viscosimeter, the cup and ball instrument, and analysis for carbon in deposits.

February. (Regular meeting) O. Frohman, Ampco Metal Co., presented a paper entitled "Gears

(Continued on p. 132)

A·S·L·E LUBRICATION NEWS

1955 ASLE MEETING AND EXHIBIT

HOTEL SHERMAN, CHICAGO, APRIL 13-14-15

J. W. Hopkinson (ASLE President), Penn-Petroleum Corp.

Chicago Skyline as photographed from the John G. Shedd Aquarium. (Courtesy, Kaufman & Fabry Co.)

PRESIDENT'S WELCOME. It is a privilege to welcome you to the 10th Annual Meeting & Exhibit of the American Socitey of Lubrication Engineers. ASLE has as its primary aim the serving of the needs of all who are connected with the field of lubrication, and your Officers, Directors, Committees, and National Office Staff are continuing to further this aim. For this annual meeting, the Program Committee, with the assistance of the Technical and Chicago Annual Meeting Committees, has planned a series of papers of outstanding calibre, arranged in unified sessions and balanced to suit the needs of all. In addition to the technical sessions and panel discussions, our Annual Exhibit of the products of the lubricant manufacturers, of lubricants application, and of other products relating to activities of the lubrication engineer, will be on display enabling the lubrication engineer to keep up-to-date with the latest developments in his profession. The Ladies Program Committee has provided a social program for the ladies which will help make their stay in Chicago a memorable one. It is hoped that each of you will find this visit to Chicago both profitable and enjoyable, and one long to be remembered.

WELCOME TO CHICAGO, by A. B. Two (Chairman of the Chicago Section), Ford Motor Co.

The Chicago Section is certainly most happy to welcome you to the 10th Annual Meeting of the American Society of Lubrication Engineers. We in Chicago are pleased to be your host Section and have planned to assist you in making your stay with us both profitable and enjoyable.

ASLE as it is now constituted was founded in Chicago in 1945. The prime factor and leader in establishing our Society at that time was the late Walter Hodson, Sr. (Others assisting Walter Hodson in this resultant most successful endeavor were: Walter Alexandroff, John Boyd, H. E. Bergman, Dr. W. E. Campbell, Sherman M. Fairchild, Allen Manteuffel, Robert Regan, William Youngclaus, Oscar Maag, Robert Kraus, and J. N. Waddel.) Being founded here it follows that the Chicago Section was the first section formed by the Society. Our current membership, well over two hundred, is representative of all types of industry in this area.

Chicago, the Windy City, got

its start in 1804, when the Federal government built Fort Dearborn on the south bank of the river. Since then the growth of our city has been continuous until today this mid-western city and its environs have the world's largest stockyards, largest manufacturing plant under one roof, the largest hotel, largest petroleum refinery processing a complete line of products, the greatest railroad center and grain market, the only river whose flow is away from its mouth, and the building with the greatest amount of floor space of any building in the world. However, in spite of this, Chicago is made up essentially of relatively small enterprises, there being over ten thousand manufacturing concerns in this area, all diversified. Besides industry and commerce, Chicago has educational and cultural assets in proportion to its size; there is located here the Illinois Institute of Technology, the only institution of higher learning in the country where an engineering degree can be earned entirely by night school attendance.

It is our sincere hope that your visit to Chicago and to the Society's 10th Annual Meeting & Exhibit will meet with your every expectation.

WELCOME TO THE VISITING LADIES, by Mrs. J. J. Slomer, Chairman of the Ladies Program Committee.

The Chicago Section welcomes the wives and guests of members attending the 10th ASLE Annual Meeting, and has planned a program to make their visit both interesting and entertaining.

Following registration on Wednesday, the ladies will be conducted on a behind-the-scenes tour of Marshall Field & Company, one of the largest and best known stores in the world. (Servicing charge customers in every country except Tibet, M. F. & Co., has furnished palaces and one room apartments; has gift-wrapped the wedding presents of princesses and fifth-generation Chicagoans. Most renowned of Field's four hundred departments is the great oval "28 Shop" famed for its lush decor and exclusive fashions by American and European designers.) Luncheon and a style show in the famed Narcissus Room will conclude the tour of M. F. & Co.

Then on to the Chicago Public Library, one of the largest circulating libraries in the world. Founded in 1871 as the direct result of a donation of more than 12,000 volumes assembled in London and presented to Chicago by British sympathizers after the great Chicago fire, it now houses more than two million volumes.

Then to The Lakeside Press (R. R. Donnelley & Sons Co.) where each week over four million copies of "Life" magazine and a million copies of "Time" are printed. (They also print "Look," telephone directories for over a thousand different cities, fifty million mail order catalogs a year for companies like Sears, Roebuck and Montgomery Ward, and three of the largest encyclopaedias in the world: "Encyclopaedia Britannica, World Book," and "Compton's.")

Thursday will begin with a tour of the Sears, Roebuck & Co. Mail Order House, and their Testing Laboratory whose purpose is to take the guesswork out of buying and to guard the quality of the company's merchandise, followed by a visit to the Garfield Park Conservatory. Luncheon will be served at the famed Kungsholm Scandinavian Restaurant, followed by a guided tour thru the Chicago Natural History Museum.

Friday, if sufficient interest is shown, a trip to the Museum of Science & Industry will be arranged, followed by visitation to the "Welcome Travelers" television show.

A. B. Wilder (Chairman of the National Meeting Committee), E. I. duPont deNemours & Co., Inc.

J. L. Finkelmann (Chairman of the Annual Meeting Program Committee), The Warren Refining & Chemical Co.

Chicago Annual Meeting Committee: Pictured from left to right (at table): A. B. Two (Chicago Section Chrmn.), Ford Motor Co.; A. B. Wilder (National Meeting Committee Chrmn.), E. I. duPont deNemours & Co., Inc.; and W. A. Alexandroff, Pate Oil Co.; (standing) P. V. Toffoli, Jr., The Pure Oil Co.; A. A. Paul, The Brooks Oil Co.; C. Benedict, Fawcett Publications; W. P. Green, Armour Research Foundation; and J. W. Peterson, Standard Oil Co. (Ind.).

Dr. HUBERT N. ALYEA, of Princeton University, has been chosen as guest speaker for the Annual Meeting Banquet. In **"Atomic Energy: Weapon For Peace,"** Dr. Alyea will trace the growth of ideas which led to the atomic bomb: of the vain attempts of the alchemists of the Middle Ages to transmute lead into gold; of Becquerl's accidental discovery of radioactivity, and of the Curies' isolation of radium; of Rutherford's interpretation of radioactive disintegration and the nuclear atom, and of his achievement of artificial transmutation. How gradually we came to understand atomic structure, and isotopes, and how to smash atoms. He will contrast the actions of ordinary high explosives with those of nuclear fission reactions, and outline the work of the Manhattan Project in exploiting these reactions. The nature of the H-fission bomb will be discussed, and a full treatment of the atomic pile will outline the various ways that new elements are produced in it.

(Following graduation from Princeton University in 1925, Dr. Alyea spent a year at the Nobel Institute, Stockholm, returning to receive his Doctor's degree from Princeton in 1929. The following year was spent at the University of Minnesota studying the chemical effects of radium, and the next year at the Kaiser Wilhelm Institute in Berlin investigating the explosion of gases. Since then he has been in the Chemistry Department of Princeton where his field of research includes plastics, retarding chemical reactions, and the action of light, radium, etc., on these reactions.)

10th ASLE Annual Meeting

PROGRAM

WEDNESDAY, April 13

8:00 am, Registration, Mezzanine.

Technical Sessions Fees: Members $3.00; Non-Members $5.00 of which $2.00 may be credited towards membership in the Society if application is made within thirty days after the Annual Meeting.

Lubrication Engineering Course Fees: Members $10.00; Non-Members $15.00. This registration fee covers the five Sessions in the Lubrication Engineering Training Course to be held concurrently with the Technical Sessions and gives all such registrants the full privileges accorded the Technical Sessions Registrants.

Exhibit Registration: The Exhibit area is open to all registrants without charge, and is open to all visitors who register.

9:00 am, Official Opening of Exhibits (Exhibition Hall), and **Annual Business Meeting.**

10:00 am

1A SESSION (Assembly Room), **Present Thinking In Gear Lubrication;** L. O. Witzenburg, The Farval Corp., Chrmn.

Gear Lubrication In The Steel Industry, by J. P. Critchlow, Gulf Oil Corp.

Worm Gear Reducers—Design & Operation, by R. B. Moir & S. D. Craine, W. A. Jones Fdry. & Mach. Co.

1B SESSION (Bal Taborin), **Plant Safety As Related To Lubrication** (Symposium); D. T. Vaughan, Aetna Casualty & Surety Co., Chrmn. Sponsored by the ASLE Technical Committee on Lubrication Equipment.

Improved Safety With Fire Resistant Hydraulic Fluids, by Dr. W. H. Millett, Carbide & Carbon Chem. Co.

Safety Aspects Of Centralized Lubrication, The, by J. W. Lander, Wheeling Steel Corp.

Lubricants Dispensing Equipment In Metal Working Machinery Operation, by M. A. Cavanaugh, The Budd Co.

12:30 pm, ASLE Chicago Section Welcome Luncheon (Louis XVI Room).

2:00 pm

2A SESSION (Assembly Room), **Controls Of Extending The Useful Life Of Coolants While In Use** (Panel); A. A. Paul, Brooks Oil Co., Chrmn. Co-sponsored by the ASLE Technical Committees on Fluids for Metal Working, and Lubricant Reclamation & Disposal.

Maintenance Of Quality In Aluminum Sheet Rolling Oils, by Dr. J. O. McLean, Reynolds Metals Co.

Quality Control Of Grinding Coolants, by O. L. Maag & H. T. Peeples, The Timken Roller Brng. Co.

Control Of Quality Of Water Soluble Machining Coolants During Use, by J. A. Prevel, General Motors Corp.

2B SESSION (Grand Ballroom), **Industrial Dermatitis** (Panel); Dr. C. F. Livingood, Henry Ford Hospital, Chrmn.

Panel Members: **M. L. Beardslee,** General Motors Corp.; **Dr. D. J. Birmingham,** U. S. Pub. Health Serv.; **Dr. E. A. Irvin,** Ford Motor Co.; **N. H Schell,** Interntl. Harvester Co.; **Dr. J. M. Shaw,** University Hosp.; **Dr. L. F. Weber,** Univ. of Illinois; **W. C. Witham,** Armour Research Fdn.

2C SESSION (Crystal Room), **Modern Concepts Of Wear, I—Radioactive Techniques;** Dr. M. E. Merchant, Cincinnati Milling Mach. Co., Chrmn. Co-sponsored by the ASLE Technical Committees on Bearings & Bearing Lubrication, and Lubrication Fundamentals.

Neutrons, Gamma Rays & Wear, by A. Hundere, G. C. Lawrason & J. P. O'Meara, Southwest Research Inst.

Atoms Trace The Wear, by H. R. Jackson & W. R. Miller, The Atlantic Refg. Co.

Radioactive Study Of The Metal Cutting Process, A, by Dr. I. Finnie, Shell Development Co., & E. Rabinowicz, Mass. Inst. of Tech.

Wear Studies With Radioactive Gears, by V. N. Borsoff, Shell Development Co.

2D SESSION (Old Chicago Room), **Education Session I;** Dr. W. E. Campbell, Brush Labs. Co., Clevite Corp., & Dr. D. D. Fuller, Columbia University, Co-Chrmn.

Introduction; Motivation of the course; Fundamentals of fluid film lubrication; Fundamentals of non-fluid film lubrication; Dry friction; Solid lubricants.

6:00 pm, Equipment & Products Display. Exhibits open to visitors until 10:00 pm.

THURSDAY, April 14

9:00 am

3A SESSION (Assembly Room), **Measuring Properties Of Lubricants;** M. L. Langworthy, The Texas Co., Chrmn. Sponsored by the ASLE Technical Committee on Physical Properties of Lubricants.

X-Ray Methods Applied To Automotive & Petroleum Research, by Dr. F. W. Lamb, Ethyl Corp.

Deposit Analysis In Lubrication Problems, by P. B. Burgess & J. F. Wygant, Standard Oil Co. (Ind.)

Effect Of Pressure & Molecular Weight Upon The Viscosity Of Polybutenes, The, by L. B. Sargent, Jr., Aluminum Research Labs.

Factors Influencing Humidity Cabinet Test Results, by H. W. Hartung, The Atlantic Refg. Co.

3B SESSION (Crystal Room), **Modern Concepts Of Wear, II;** Dr. W. E. Campbell, Brush Labs. Co., Clevite Corp., Chrmn. Co-sponsored by the ASLE Technical Committees on Bearings & Bearing Lubrication, and Lubrication Fundamentals.

Survey Of Wear Mechanisms, by J. T. Burwell, Jr., Horizons, Inc.

Study Of The Sliding Of Metals With Particular Reference To Atmosphere, A, by L. F. Coffin, Jr., General Electric Co.

Wear Of Iron In Sliding Contact With Various Elemental Metals, The, by C. L. Goodzeit, R. P. Hunnicutt & A. E. Roach, General Motors Corp.

Effects Of Sliding Velocity & Temperature On Wear & Friction Of Several Materials, by R. L. Johnson, M. A. Swikert & E. E. Bisson, NACA, Lewis Flight Prop. Lab.

3C SESSION (Grand Ballroom), **Organization Of A Plant Lubrication Program** (Panel); H. D. Krummell, Socony-Vacuum Oil Co., Chrmn. Sponsored by the ASLE Technical Committee on Principles & Practices of Economic Lubrication.

Panel Members: **O. J. Seidl,** Combustion Engrg., Inc.; **A. Bolden,** Continental Motors Corp.; **C. G. Hollister,** The Bakelite Co.

3D SESSION (Old Chicago Room), **Education Session II;** C. A. Bailey, U. S. Steel Corp., Chrmn.

Properties of lubricants; Petroleum oils and greases; Synthetic oils and greases; Tests and their significance.

3E SESSION, Plant Tour of Sinclair Laboratories, Harvey, Ill. Sponsored by the ASLE Chicago Section.

2:00 pm

4A SESSION (Grand Ballroom), **Lubricant Dispensing Equipment & Application;** E. M. Higgins, Master Lubricant Co., Chrmn. Sponsored by the ASLE Technical Committee on Lubrication Equipment.

Centralized Grease Lubrication Equipment, by L. T. McDonald, Wheeling Steel Corp.

Economic Factors Of Centralized Lubrication, The, by R. C. Lohbauer, Snyder Tool & Engrg. Co.

Critical Survey Of Industrial Lubrication Engineering In Great Britain & The U.S.A., A, by G. D. Jordan, Samuel Fox & Co., Ltd.

4B SESSION (Crystal Room), **Rolling Contact Bearings;** E. F. Macks, Consulting Engineer, Chrmn. Sponsored by the ASLE Technical Committee on Bearings & Bearing Lubrication.

Integrally Sealed Ball Bearings, by L. D. Cobb, General Motors Corp.

Some Unusual Conditions Encountered In The Lubrication Of Anti-Friction Bearings, by T. W. Morrison, SKF Industries, Inc.

Lubrication Of Rolling Contact Bearings At Elevated Temperatures With Solid, Liquid & Gaseous Lubricants, by Z. N. Nemeth & W. J. Anderson, NACA, Lewis Flight Prop. Lab.

4C SESSION (Assembly Room), **Timely Studies In Friction;** Dr. R. G. Larson, Shell Oil Co., Chrmn. Sponsored by the ASLE Technical Committee on Lubrication Fundamentals.

Factors Influencing Friction & Wear With Solid Lubricants, by M. B. Peterson & R. L. Johnson, NACA, Lewis Flight Prop. Lab.

Influence Of Moisture On The Friction & Surface Damage Of Clean Metals, The, by R. O. Daniels & A. C. West, California Research Corp.

Frictional Characteristics Of Plastics, by W. C. Milz & L. P. Sargent, Jr., Aluminum Research Labs.

High Speed Friction & Wear Machine, A, by H. G. Clarke, Jr., & W. W. Shugarts, Jr., The Franklin Institute.

4D SESSION (Old Chicago Room), **Education Session III;** R. J. Torrens, Eastman Kodak Co., Chrmn.

Application of lubricants; Continuous flow circulating systems; Intermittent flow systems for oils and greases; Commercial types; Lubricating cups and fittings, etc; Maintenance of lubricating systems and lubricators.

6:30 pm, Cocktail Party & Annual Banquet (Informal).

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FRIDAY, April 15

9:00 am

5A SESSION (Grand Ballroom), **Bearings & Lubrication;** A. A. Raimondi, Westinghouse Electric Co., Chrmn. Sponsored by the ASLE Technical Committee on Bearings & Bearing Lubrication.

New Method For The Determination Of Attitude & Eccentricity In Journal Bearings, A, by B. Sternlicht, General Electric Co., & Dr. D. D. Fuller, Columbia Univ.

Rheodynamic Squeeze-Film, The, by F. Osterle, A. Charnes & Dr. E. Saibel, Carnegie Inst. of Tech.

New Bearing Metal Theory In Which Lubrication Is An Important Factor, A, by Dr. B. Lunn, N. Cable & Wire Wks., Ltd.

5B SESSION (Assembly Room), **Metal Working;** Dr. A. O. Schmidt, Kearney & Trecker Corp., Chrmn. Sponsored by the ASLE Technical Committee on Fluids for Metal Working.

Sliding Friction Test For Metalworking Lubricants, by W. J. Wojtowicz, H. A. Montgomery Co.

Use Of A Glass Lubricant In The Extrusion Of Steel, by J. Sejournet & J. Delcroix, Comptoir d'Etirage, France; presented by J. Strauss, Vanadium Corp.

Soluble Oils—Handle With Care, by A. A. Manteuffel, The Pure Oil Co.

Tool Weight Loss For Cutting Fluid Evaluation, by J. P. G. Beiswanger, J. P. Copes & R. L. Mayhew, Gen. Aniline & Film Corp.

5C SESSION (Bal Taborin), **Greases;** H. W. McCulloch, Jr., Shell Oil Co., Chrmn. Sponsored by the ASLE Technical Committee on Physical Properties of Lubricants.

Evaluation Of Lubricating Grease Compatibility, by A. L. McClellan & S. R. Calish, Jr., California Research Corp.

Corrosion Inhibited Greases, by R. F. Repenning, Shell Oil Co.

Low Temperature Operation Of Aircraft Accessories, by E. A. Baniak & R. S. Barnett, The Texas Co.

5D SESSION (Old Chicago Room), **Education Session IV;** W. T. Everitt, Eastman Kodak Co., Chrmn.

Ball and roller bearing application and maintenance; Journal bearing grooving; Oil seals, gaskets and packing; Gear lubrication.

5E SESSION, Plant Tour of The Pure Oil Refinery, Lamont, Illinois. Sponsored by the ASLE Chicago Section.

10:00 am, Business Meeting of ASLE Officers & Directors.

2:00 pm

6A SESSION (Assembly Room), **General Industry;** G. Spehn, D. A. Stuart Oil Co., Chrmn.

Water Base Fire Resistant Hydraulic Fluids In Aircraft Carrier Catapults, by C. R. Schmitt, E. F. Houghton & Co.

Nature & Performance Of Some Inorganic Base Greases, by W. H. Peterson & A. Bondi, Shell Development Co.

Pumpability Of Aircraft Turbine Lubricants At Low Temperatures, by E. S. Starkman, University of Calif., & Lt. J. H. Bridges, U.S.N.

Progress Report On Silicone Lubricants, A, by H. F. Lamoreaux, General Electric Co.

6B SESSION (Grand Ballroom), **Modern Concepts Of Wear, III;** Dr. D. F. Wilcock, General Electric Co., Chrmn. Co-sponsored by the ASLE Technical Committees on Bearings & Bearing Lubrication, and Lubrication Fundamentals.

Electron Microscope Study Of Lubrication & Wear, by Drs. S. B. Twiss, C. R. Lewis & D. M. Teague, Chrysler Corp.

Adhesive Wear Of Metals, by C. D. Strang, Jr., Kiekhaefer Corp.

Study Of Fretting Wear In Mineral Oil, A, by D. Godfrey, California Research Corp.

Mass & Energy Balance For The Wear Process, A, by P. F. Chenea, Purdue University, & A. E. Roach, General Motors Corp.

6C SESSION (Old Chicago Room), **Education Session V;** K. S. Smiley, E. I. duPont deNemours & Co., Inc., Chrmn.

Plant lubrication; Lubrication schedules; Storage and handling; Selection of proper lubricants; Analyses of failure; The principles of economic lubrication.

LADIES' PROGRAM

TUESDAY, April 12

8:00 pm, Early Registration, Mezzanine.

WEDNESDAY, April 13

8:00 am, Registration, Mezzanine.
9:30 am, Behind-the-Scenes Tour of Marshall Field & Company.
11:45 am, Luncheon & Style Show, Marshall Field & Co., Narcissus Room.
1:00 pm, Tour of Chicago Public Library.
2:00 pm, Tour of Lake Side Press.

THURSDAY, April 14

9:00 am, Tour of Sears, Roebuck & Co. Mail Order House & Testing Laboratory.
11:15 am, Tour of Garfield Park Conservatory & Easter Flower Show.
12:30 pm, Smorgasbord luncheon at Kungsholm Scandinavian Restaurant.
2:30 pm, Tour of Chicago Natural History Museum.

FRIDAY, April 15

9:30 am, Tour of Museum of Science & Industry.
12:00 nn, "Welcome Travelers" Television Show.

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Annual Meeting Authors

Pictured below are the authors of papers to be presented at the 10th ASLE Annual Meeting, Hotel Sherman, Chicago, Illinois, April 13-14-15, 1955. Abstracts of papers follow (except for those arriving too late to meet publication deadlines); they do not necessarily represent the final opinions of the authors and are subject to revision when the complete papers are published.

W. J. ANDERSON
NACA, Lewis Flight Propulsion Lab.

E. A. BANIAK
The Texas Co.

R. S. BARNETT
The Texas Co.

M. L. BEARDSLEE
General Motors Corp.

P. G. BEISWANGER
General Aniline & Film Corp.

Dr. D. J. BIRMINGHAM
U. S. Public Health Service

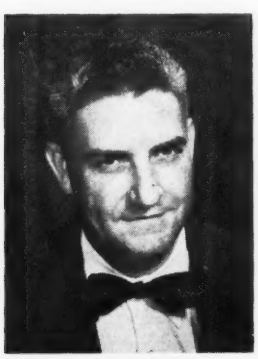
E. E. BISSON
NACA, Lewis Flight Propulsion Lab.

A. BONDI
Shell Development Co.

V. N. BORSOFF
Shell Development Co.

P. B. BURGESS
Standard Oil Co. (Ind.)

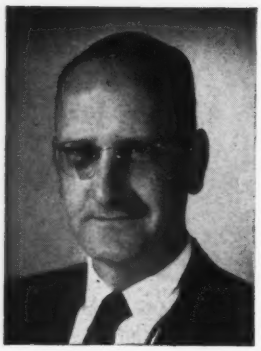
S. R. CALISH, Jr.
California Research Corp.



M. A. CAVANAUGH
The Budd Co.

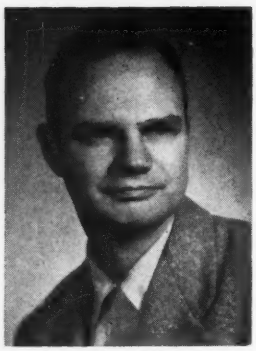
P. F. CHENEA
Purdue University

H. G. CLARKE, Jr.
The Franklin Institute



L. D. COBB
General Motors Corp.

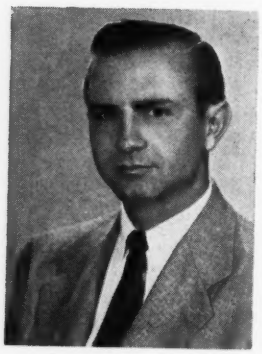
L. F. COFFIN, Jr.
General Electric Co.



J. P. COPES
General Aniline & Film Corp.

S. D. CRAINE
W. A. Jones Foundry & Machine Co.

J. P. CRITCHLOW
Gulf Oil Corp.



R. O. DANIELS
California Research Corp.

J. DELCROIX
Comptoir d'Etirage

Dr. I. FINNIE
Shell Development Co.

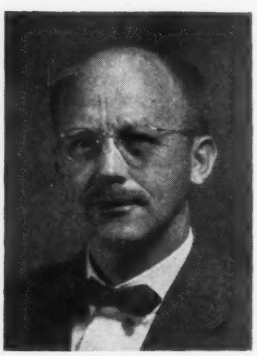
Dr. D. D. FULLER
Columbia University

D. GODFREY
California Research Corp.

C. L. GOODZEIT
General Motors Corp.

H. W. HARTUNG
The Atlantic Refining Co.

C. G. HOLLISTER
The Bakelite Co.



A. HUNDERE
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General Motors Corp.

Dr. E. A. IRVIN
Ford Motor Co.

H. R. JACKSON
The Atlantic Refining Co.

R. L. JOHNSON
NACA, Lewis Flight Propulsion Lab.

G. D. JORDAN
Samuel Fox & Co., Ltd.

Dr. F. W. LAMB
Ethyl Corp.

J. W. LANDER
Wheeling Steel Corp.

G. C. LAWRASON
Southwest Research Institute

Dr. C. R. LEWIS
Chrysler Corp.

R. C. LOHBAUER
Snyder Tool & Engineering Co.

Dr. B. LUNN
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A. L. McCLELLAN
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L. T. McDONALD
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Dr. J. O. McLEAN
Reynolds Metals Co.

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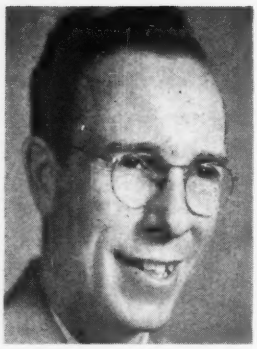
Carbide & Carbon Chemicals Co.



W. C. MILZ
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R. B. MOIR
W. A. Jones Foundry & Machine Co.

Z. N. NEMETH
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J. P. O'MEARA
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F. OSTERLE
Carnegie Institute of Technology

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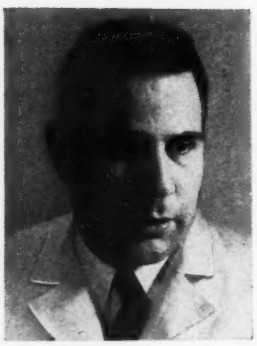
NACA, Lewis Flight Propulsion Lab.

J. A. PREVEL
General Motors Corp.

E. RABINOWICZ
Massachusetts Institute of Technology

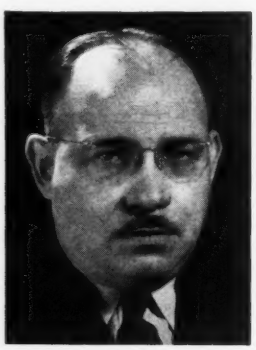
R. F. REPENNING
Shell Oil Co.



A. E. ROACH
General Motors Corp.

Dr. E. SAIBEL
Carnegie Institute of Technology

L. B. SARGENT, Jr.
Aluminum Research Laboratories



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C. R. SCHMITT
E. F. Houghton & Co.

O. J. SEIDL
Combustion Engineering, Inc.

J. SEJOURNET
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Dr. J. M. SHAW
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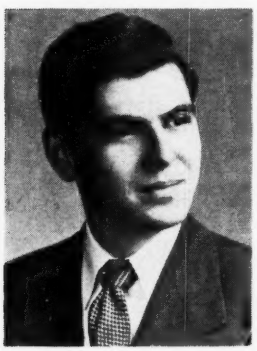
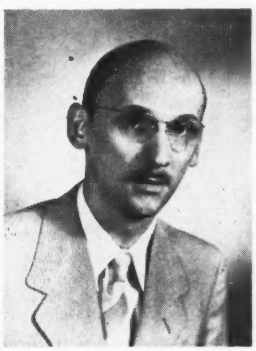


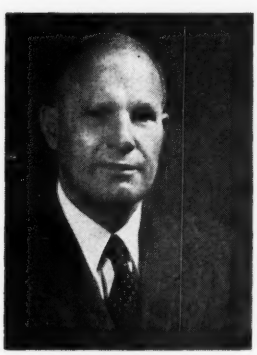
B. STERNLICHT
General Electric Co.

M. A. SWIKERT
NACA, Lewis Flight Propulsion Lab.



Dr. D. M. TEAGUE
Chrysler Corp.

Dr. S. B. TWISS
Chrysler Corp.



Dr. L. F. WEBER
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A. C. WEST
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Annual Meeting Abstracts

The following abstracts of papers to be presented at the 1955 ASLE Annual Meeting, Hotel Sherman, Chicago, April 13-14-15, are published herewith for general information and to stimulate discussion at the meeting.

Adhesive Wear Of Metals, by C. D. Strang, Jr. (Kiekhaefer Corp.). Limiting the discussion to wear of clean metals in the absence of loose abrasive materials or corrosive agents, this paper relates recent experimental attempts to determine the mechanism of metallic wear and discusses the empirical relationships derived therefrom. Subject is treated from the viewpoint of the widely accepted theories of dry friction and surface deformation as postulated by Bowden, Tabor, Holm, and others. Practically speaking, the results serve to explain much of the phenomenon of "run-in."

Atoms Trace The Wear, by H. R. Jackson & W. R. Miller (The Atlantic Refining Co.). The technique of using radioactive piston rings to study wear in internal combustion engines is covered with respect to equipment, training, and safety. Both single cylinder laboratory tests, and service type tests are discussed. The relative occurrence of corrosive and abrasive wear, and the factors of lubricant, fuel, and operation that affect them are covered.

Centralized Grease Lubrication Equipment, by L. T. McDonald (Wheeling Steel Corp.). A discussion will be given on the fundamental design and operation of centralized grease lubrication equipment. Some of the factors to be considered in the practical selection and installation of such equipment will be presented. The possibilities in elimination of contaminants through the proper handling of the lubricant from barrel to bearing will be pointed out, and a review of some of the combinations that can be made in application of centralized equipment offered.

Composition & Action Of Protective Ointments, The (Industrial Dermatitis Panel), by Dr. J. M. Shaw (University Hospital). This presentation deals with the history of protective ointments, their basic composition, and special emphasis on recent improvements in the barrier cream field. An explanation of the mode of action of the various ointments will be presented.

Control Of Quality Of Water Soluble Machining Coolants During Use (Panel), by J. A. Prevel (General Motors Corp.). The use of soluble machining coolants has increased tremendously in recent years through the introduction of so-called heavy duty soluble coolants. Also many machines have been designed to use soluble machining coolants which was not possible before. The use of soluble machining coolants has many advantages in machining operations, but care should be taken to control the coolant to insure good results. Accurate, but practical methods of control in the shop can extend the life of the coolants in the machines. Methods of control include physical and chemical, depending on the conditions encountered.

Corrosion Inhibited Greases, by R. F. Repenning(Shell Oil Co.). The purpose of this paper is to discuss multi-purpose greases with specific built-in water corrosion protective properties. A steadily mounting need for such products in the industrial and automotive fields has been indicated. They should be capable of providing maximum protection to antifriction bearings and precision steel parts under wet and intermittent operating conditions at minimum service intervals. Interesting data and slides will be presented in support of conclusions drawn during an investigation of the problem. Multi-purpose greases possessing the required properties have been developed and are offered as a solution to the problem.

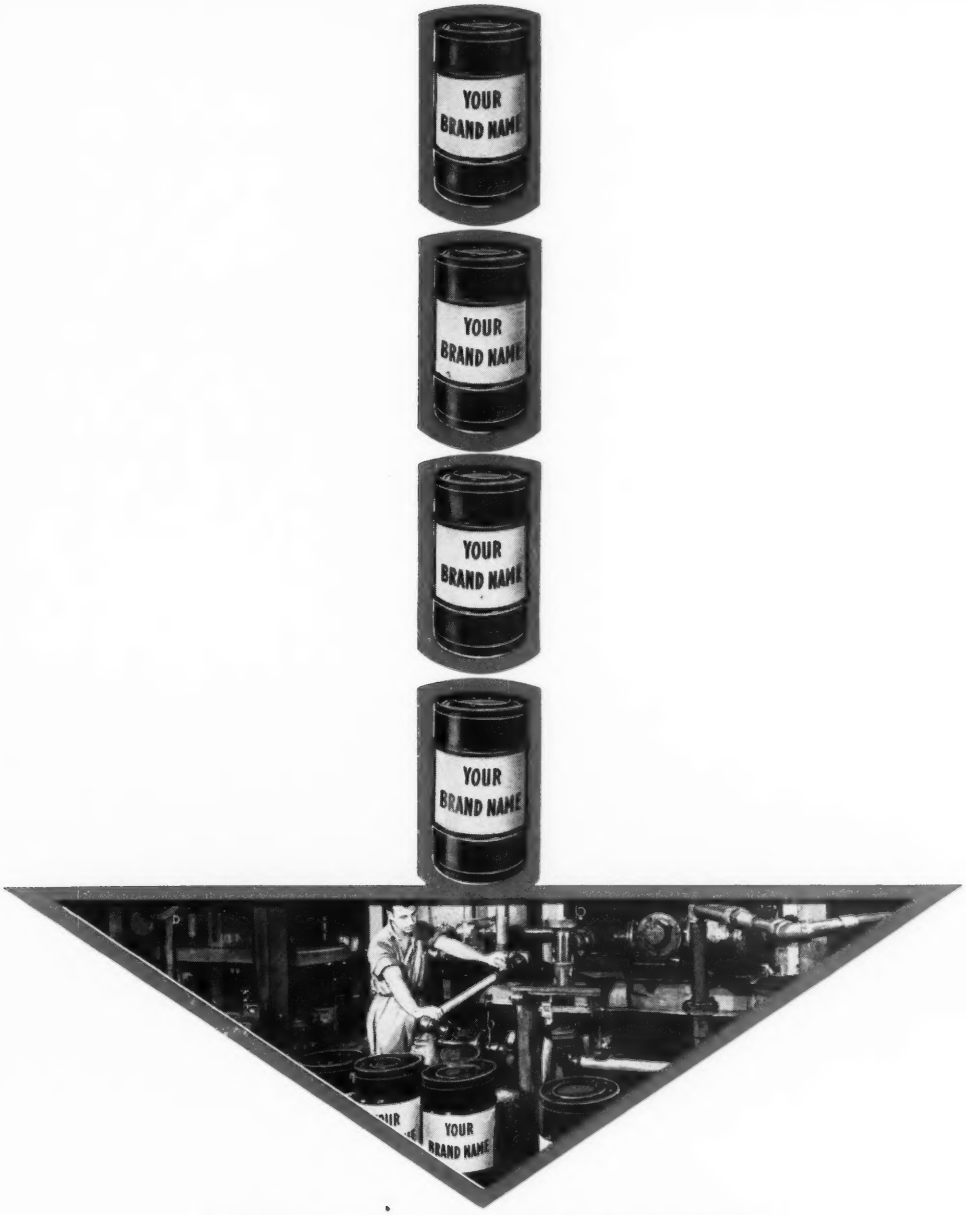
Critical Survey Of Industrial Lubrication Engineering In Great Britain & The U. S. A.,A, by G. D. Jordan (Samuel Fox & Co., Ltd.). Lubrication engineers have been active in the U.S.A. since the early '20s but it is only over the last 10 years or so that they have achieved full recognition. In Great Britain lubrication engineers have been active over the past 6 or 7 years. In the U.S.A. there appear to be three classes of industrial lubrication engineer: the plant, the division, and the chief lubrication engineer. In Great Britain there are as yet no chief lubrication engineers of a comparative nature. Details are given of the structure of the lubrication department and the line of responsibility of the lubrication engineer in the Engineering Department organization. The apparent reasons for the appointment of lubrication engineers in industry are outlined. Comparisons are drawn between the methods employed by the lubrication engineers in the two countries in effecting their work. The types of lubricants used and methods of application are discussed briefly, and suggestions are made for improving industrial lubrication engineering from "lessons learned," in touring steel works in Great Britain and the U.S.A.

Deposit Analysis In Lubrication Problems, by P. B. Burgess & J. F. Wygant (Standard Oil Co. (Ind.)). By identification of the phases present in deposits, valuable assistance in solution of lubrication problems may be obtained. A scheme or organic and inorganic phase analysis depending primarily on solvent extraction, X-ray diffraction analysis, and petrographic examination is presented for both routine and investigative purposes. The interpretation of results in terms of operating conditions and causes of lubrication difficulties is discussed.

Economic Factors Of Centralized Lubrication, The, by R. C. Lohbauer (Snyder Tool & Engineering Co.). The object of this paper is to show that, despite the tremendous improvements made in lubricants, bearings and methods of controlling the application of one to the other, millions of dollars are still being wasted in industry because of machine failures caused by faulty lubrication. The human element and improper application of lubricants are at the root of this trouble which can only be corrected by "controlled application." It will be clearly demonstrated how, as a result of a study and survey of machinery in a large automotive parts manufacturing plant, lubrication practices were found to be responsible for constant down time and excessive maintenance costs. The corrective measures taken and the resultant cost reductions proved to be astounding.

Effect Of Pressure & Molecular Weight Upon The Viscosity Of Polybutenes, The, by L. B. Sargent, Jr. (Aluminum Research Laboratories). The purpose of the investigation described was to determine the influence of molecular weight and molecular weight distribution upon the viscosity of polybutylenes, particularly over a range of pressures. A rolling ball viscometer and conventional pressure generating and measuring equipment was used. The experimental data indicate that average molecular weights of polybutylene blends do not fully reveal the true nature of the viscosity properties of these liquids. The polymer blends behave, from a viscosity standpoint, as though their average molecular weights are somewhat lower than actual molecular weight measurements reveal. Applications of the reaction-rate theory of viscosity complement the experimental observations and indicate mathematically that the average molecular weight of a polybutylene polymer is not as useful as the molecular weight distribution in the blend for predicting the viscosity behavior of these fluids under varying conditions of pressure and temperature.

Effects Of Sliding Velocity & Temperature On Wear & Friction Of Several Materials, by R. L. Johnson, M. A. Swikert & E. E. Bisson (NACA, Lewis Flight Propulsion Laboratory). Wear experiments were conducted with leaded



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brass, iron silicon bronze, cast Inconel and nodular iron sliding against hardened steel. Separate series of data showed the effect of sliding velocity up to 18,000 feet per minute in room temperature runs and also the influence of ambient temperatures up to 1000 F., in runs made at low sliding velocity. Both sliding velocity and temperature had considerable effect on wear of unlubricated surfaces. The effects, however, were markedly different for the different metals. Changes in wear properties may have resulted from effect of temperature on physical properties and on the formation of oxide films. NiO films on cast Inconel are necessary in order to obtain low wear; in air, rate of wear decreased with increasing temperatures as oxides were more readily formed. Copper alloys had higher wear rates at 450 F., when lubricated with a diester than when run without lubrication. Other materials did not show this tendency.

Electron Microscope Study Of Lubrication & Wear, by S. B. Twiss, C. R. Lewis & D. M. Teague (Chrysler Corp.). The specimens used in this study were crossed steel cylinders, one cylinder rotating, the other being stationary. Under these conditions of high unit loading, wear particle size, damage of the metal contact surface, and wear rate increase with increasing original surface roughness of the moving metal part. The type of lubricant strongly affects the wear process. Wear with purified mineral oil produces extremely minute particles, possibly by extensive and continuous microscopic welding of the sliding surfaces, due to rupture of the simple hydrocarbon film under the high unit loads. In contrast, ethyl palmitate or a 5% addition of sperm oil to mineral oil provides improved boundary lubrication, larger and fewer wear particles, little welding, and an extremely smooth surface except for occasional deep scratches.

Evaluation Of Lubricating Grease Compatibility, by A. L. McClellan & S. R. Calish (California Research Corp.). Mixing of two or more lubricating greases of different soap bases in the laboratory by simply stirring them together produces some unusual effects upon the physical properties of the resulting blend. Data are quoted for ASTM dropping point and ASTM grease worker tests to illustrate these effects upon typical mixtures. Further, more complicated laboratory performance tests demonstrate that these effects are real and can impair the performance of mixtures in service. Appropriate examples of incompatibility encountered in service are described.

Factors Influencing Friction & Wear With Solid Lubricants, by M. B. Peterson & R. L. Johnson (NACA, Lewis Flight Propulsion Laboratory). An experimental study of solid lubricants and the factors that influence their lubricating effectiveness. The research was conducted using a low speed friction and wear apparatus with steel test specimens. The lubricants were all used in the powder form. Most data were obtained with MoS_2, but other solid lubricants were also studied. Moisture is harmful to lubrication with MoS_2, but may be a necessity for effective lubrication under some conditions with other solid lubricants. Lubrication effectiveness of MoS_2 improves with increasing temperatures which minimize the effects of moisture. Very small amounts of abrasive contaminants in solid lubricants can have considerable effect on wear. Mixtures of MoS_2 and oil must contain at least 10 percent of either MoS_2 or oil to obtain the minimum range of friction coefficients. Structure can be a useful guide in the selection of solid lubricants with low shear strength. However, ability of the solid to form an adherent film on the surface to be lubricated is the primary esential for good lubrication by solids.

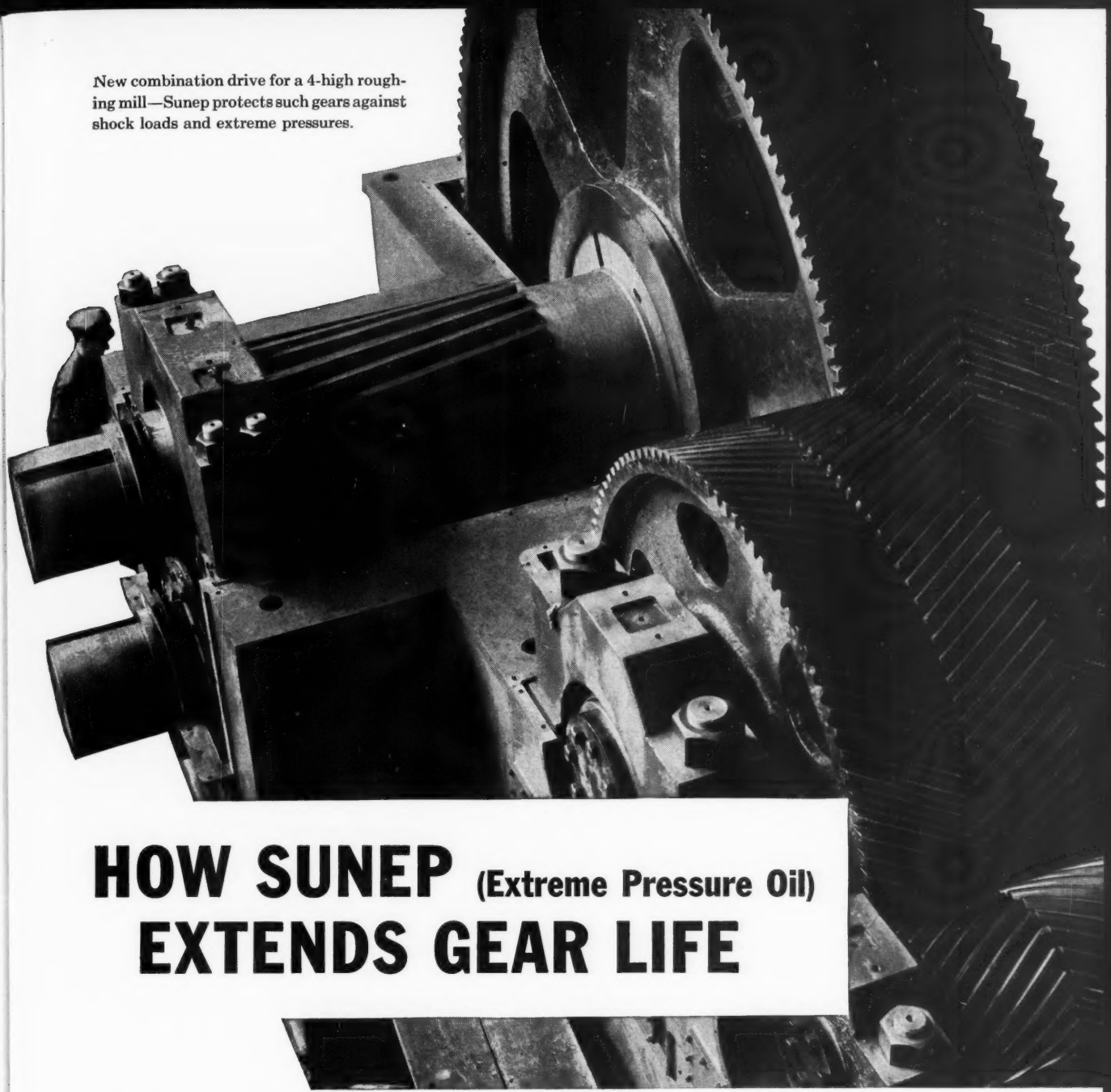
Factors Influencing Humidity Cabinet Test Results, by H. W. Hartung (The Atlantic Refining Co.). Conventional humidity cabinets generally have two major weaknesses: (1) results show poor reproducibility, and (2) they correlate poorly with field test results. Reproducibility is affected by a number of factors in cabinet operation that are frequently uncontrolled. A study of these factors, made in a specially constructed, simple cabinet, shows that reproducibility can be greatly improved. The influence of panel preparation is considerable, as shown by tests on several types of specimens prepared by a number of different methods. Correlation with field results depend on other factors which are discussed in a preliminary way.

Frictional Characteristics Of Plastics, by W. C. Milz & L. P. Sargent, Jr. (Aluminum Research Laboratories). In industry there are many actual and potential applications for plastics, especially in the field of bearing design, where knowledge of their frictional characteristics would be of benefit. For this reason a study has been made of the frictional characteristics of seventeen plastic materials. The tests were performed on the Crossed Cylinders apparatus, a sensitive friction measuring device, at various loads and speeds under dry, water, and oil lubricated conditions. Teflon and several filled Teflons have exceptionally low and almost equivalent friction values, especially at low rubbing speeds, thus proving that thermal and/or structural properties of Teflon may be altered by fillers without sacrificing good frictional characteristics. Also, under many conditions some filled Teflons perform as well with water as with oil lubrication. Polystryene has "dry" friction coefficient equivalent to or lower than Teflon type plastics at high speeds. Polyethylene equals the Teflons when using oil lubrication. Other individual performances of the plastics as well as speed, load, and lubrication effects are discussed in the body of the report.

Gear Lubrication In The Steel Industry, by J. P. Critchlow (Gulf Oil Corp.). The first phase of the paper will cover briefly the design and development of the various types of gear teeth, some of the theories of gear lubrication including the mechanism by which an oil film is formed and the various functions of the gear lubricant. The second phase of the paper will deal with the various types of gear units in the Steel Industry, the types of lubricants used, the reasons for their use, and methods for applying lubricants to gear units. The third phase will cover various types of gear tooth failure, some of the reasons for such failures and methods for overcoming same.

High Speed Friction & Wear Machine, A, by H. G. Clarke, Jr., & W. W. Shugarts, Jr. (The Franklin Institute). A high speed friction and wear machine has been developed to study sliding friction between unlubricated solids at very high speeds. Small cylindrical samples (½ in. long by ¼ in. dia.) of the material to be tested are run against plain or plated steel surfaces. The frictional resistance, the wear, and the temperature at the rubbing surface can be observed for pressures from 4000 to 24,000 psi (loads of 20 to 120 lb.) at speeds between 6000 and 120,000 fpm. The test apparatus is described in detail with the aid of drawings and photographs. A discussion is included covering the preparation of the sliding surface, the geometry and material of the test samples, the test conditions, the operational characteristics of the machine, and the experimental observations that are made. Some typical results are shown for the case of copper sliding on unlubricated steel. These indicate the general trends of frictional resistance and wear for pressures between 4000 and 24,000 psi and speeds between 9000 and 72,000 fpm. A few data are also given on surface temperatures.

Influence Of Moisture On The Friction & Surface Damage Of Clean Metals, The, by R. O. Daniels & A. C. West (California Research Corp.). A new, controlled atmosphere, low speed friction apparatus for fundamental boundary lubrication studies is described. The friction of a one-eighth inch diameter hemispherical slider on a flat disk is automatically plotted as a function of the desired operating variable on an "X-Y" type recording potentiometer. An investigation of the effects of moist surrounding atmosphere and bulk water on the kinetic friction of high purity, unlubricated metals is reported and a theory presented which explains the observed behavior in terms of an oxidizing reaction which occurs at the contacting asperities as they deform. The oxidation is accelerated at the freshly exposed metal surfaces by the presence of adsorbed moisture and by any rise in temperature



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which may occur, with the result that friction and surface damage are reduced.

Low-Temperature Operation Of Aircraft Accessories, by E. A. Baniak & R. S. Barnett (The Texas Co.). In order to investigate the performance of greases at low temperatures in actual aircraft accessory equipment, a project was set up which included the testing of five greases in five pieces of accessory equipment. Tests on each of the greases were conducted at room temperature, −65 F., and −100 F. Of the five greases tested, Greases A, B, and C were MIL-G-3278 Specification greases, Grease D was an MIL-G-7421 (USAF) Specification grease, and Grease E was a high-temperatures grease (with fair low-temperature properties) which does not meet any military specification. On the basis of a statistical analysis on the results of this investigation, the following conclusions were drawn: (1) There was as much variation in the low-temperature power requirements of the accessory units of the same design as there were variations attributable to the performance of similar greases. (2) When lubricated with MIL-G-3278 or MIL-G-7421 Specification greases, the power available was sufficient for operating low temperatures down to −100 F., in all motorized equipment except for an antenna assembly. (3) There was no definite correlation between the results of the low-temperature torque tests (carried out in No. 204 ball bearings) and the results of the tests on actual aircraft accessory equipment. (4) Grease D was superior to all other greases in low-temperature performance. (5) Greases A & B were approximately equivalent and slightly superior to Grease C. (6) Grease C was definitely superior to Grease E.

Lubrication Of Rolling Contact Bearings At Elevated Temperatures With Solid, Liquid, & Gaseous Lubricants, by Z. N. Nemeth & W. J. Anderson (NACA, Lewis Flight Propulsion Laboratory.) Experimental studies of the lubrication of 20 mm bore tool steel ball bearings with solids, liquids, and gases at temperatures to 1000 F., are reported. Tests were conducted at a speed of 2500 rpm and a thrust load of 110 pounds. Friction torque was used as the criterion of lubricating effectiveness.

Maintenance Of Quality In Aluminum Sheet Rolling Oils (Panel), by Dr. J. O. McLean (Reynolds Metals Co.). In the early stages of sheet rolling, we treated the dirty oil with concentrated sulfuric acid, centrifuged it and used it over. This method proved unsatisfactory. We then adopted the system of using the oil until it became badly contaminated, dumped a portion and added new oil. This process was wasteful and was abandoned. Our next step was to send the dirty oil out to a jobber, who purified it and returned it. This proved satisfactory, but was expensive. We then installed an elaborate by-pass filter system based on the use of adsorptive clay. This system, although possibly not the cheapest or best, is in use today. It keeps the oil fairly clean constantly, but occasions excessive loss of additive and requires large quantities of clay, which in turn causes fairly large oil losses through discarding oil soaked clay.

Mass & Energy Balance For The Wear Process, A, by P. F. Chenea (Purdue University) & A. E. Roach (General Motors Corp.). In this paper wear is treated as the process of removing particles from the interface of solid bodies that are in sliding contact. Without making any assumptions regarding the detailed mechanism of this process, the authors have derived a general equation for wear from simple mass and energy considerations. This equation establishes the constraints which must be taken into account in setting up a theory of wear. It is shown that several existing wear equations are special cases of the general equation derived in the paper.

Nature & Performance Of Some Inorganic Base Greases, by W. H. Peterson & A. Bondi (Shell Development Co.). A large number of novel gelling agents has been proposed for the preparation of lubricating greases during the past few years. Many of these have been examined by us for their suitability as bases for multipurpose greases. A summary of experimental evidence is given from which an attempt is made to deduce the general principles which appear to govern the relation between the properties of the final grease and the structure of the gelling particles and their surfaces. The need to strike a balance between a sufficiently hydrophilic particle surface to obtain the particle interaction underlying their ability to gel, and a sufficiently hydrophobic particle surface to maintain the gel intact in the presence of water, throws most of the weight of grease development on the choice and dosage of organic surfacants appropriate for the given gelling agent. This choice is further complicated by the demand that a modern multipurpose grease be able to protect bearing surfaces against corrosion. The practical result of this investigation is an industrial multipurpose grease which combines outstanding bearing performance at elevated temperatures with very satisfactory rust preventive ability and water resistance in the laboratory as well as in the field. The physical property and performance data of this inorganic base grease are used as illustrative examples for the potentialities of a new approach to grease technology.

Neutrons, Gamma Rays & Wear, by A. Hundere, G. C. Lawrason & J. P. O'Meara (Southwest Research Institute). This paper discusses one laboratory's experiences with the radioactive tracer technique for studying wear. The technique itself is discussed to emphasize its potentialities and simplicity. The highlights of eight projects in which the radioactive technique was utilized are presented. These include wear studies of both piston rings and gears. The weights of the radioactive parts involved have varied from 20 grams to over one pound. In addition to using radioactive iron rings, radioactive chrome rings have been effectively utilized.

New Bearing Metal Theory In Which Lubrication Is An Important Factor, A, by Dr. B. Lunn (Northern Cable & Wire Works, Ltd.). This paper describes a method of evaluating bearing metals under conditions of boundary lubrication. The method uses electrical measurements from which the bearing characteristics may be expressed by a single number called the "L" value. The test results show that boundary lubrication is primarily dependent upon chemical reactions between the bearing metal, the lubricant, and the atmosphere. A new theory of bearing metals, based on these reactions, is presented, and it is shown how the theory may be extended to other sliding elements.

New Method For The Determination Of Attitude & Eccentricity In Journal Bearings, A, by B. Sternlicht (General Electric Co.) & Dr. D. D. Fuller (Columbia University). This paper reports on a new method for measuring attitude and eccentricity in journal bearings. The principle is to measure the motion between a rigidly supported shaft and a floating bearing. Three types of instruments were used to measure this motion. Since the work was done in conjunction with a stability analysis of journal bearings, only eccentricity ratios in the range from 0 to 0.5 were investigated.

Organization Of A Plant Lubrication Program (Panel), by C. G. Hollister (The Bakelite Co.). Progressive management recognizes the importance of an organized lubrication program which assures through the proper type and application of lubricants, the minimum downtime on equipment and a reduction in maintenance costs. This is accomplished through the lubrication supervisor who sees that good quality lubricants are used, that there is adequate dispensing equipment, that the lubricants are properly stored and handled, and that his completely trained crew will service the equipment with the correct amount and type of lubricant at the specified frequency. The heart of the program is the competency and dependability of the lubrication mechanics, which in large measure reflects the training they have received. This training takes the form of films on the principles of lubrication, lectures on plant practices with examples of lubrication failures, and reviews of lubricant specifications and plant schedules. The work of the lubrication group is simplified by providing schedules and routes, by reducing the number of lubricants to a minimum, and then using plant code numbers to identify types and grades of lubricants.

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Organization Of A Plant Lubrication Program (Panel), by O. J. Seidl (Combustion Engineering, Inc.). A brief resume of machine lubricating procedure as previously practiced will serve to point out the need of establishing a more comprehensive program. The various items to be considered are personnel and training, equipment, lubricants and records. Discussion will include: (1) the qualifications and qualities desired in lubrication personnel and the training needed; (2) the various grease and oil guns used, the design and construction of lubrication carts, types of gun fillers employed, storage and handling of lubricants and allocation of space for exclusive use of lubricators; (3) the all important plant machinery survey to determine the number of different lubricants required, the proper coding of lubricants and the frequency with which they are to be applied; (4) the gradual development of the ever present paper work system; and (5) the benefits derived from the program both as to direct reduction in lubricating costs and examples of extended machine tool life.

Pumpability Of Aircraft Turbine Lubricants At Low Temperatures, by E. S. Starkman (University of California) & Lt. J. H. Bridges (U.S.N.). Questions regarding the principles governing flow characteristics of lubricating oils in the vicinity of the pour point have lead to an investigation into the behavior of a series of typical aircraft gas turbine lubricants in a simple system at temperatures down to −70 F. The lubricants tested included two oils of military specifications AN-09-A (a 1005 grade and a 1010 grade), a sample equivalent in viscosity to AN-09-A, but having a −15 F., pour point, and a di-2-ethyl-hexyl sebacate. Results indicated that laminar flow relationships were satisfactory for predicting flow characteristics down to the pour point so long as proper attention was paid to pump inlet conditions. In addition, there was evidence that satisfactory pumping is possible to temperature lower than the pour point, a conclusion which may be of considerable practical value.

Radioactive Study Of The Metal Cutting Process, A, by Dr. I. Finnie (Shell Development Co.) & E. Rabinowicz (Massachusetts Institute of Technology). Radioactive copper was cut in a two-dimensional planing operating with a variety of rake angles and cutting fluids. The nature of the contact between the materials and the tool was studied by taking autoradiographs of the tool faces after each cut and the magnitude of the transfer to the tool from the copper calculated. Examination of the distribution of wear fragments along the tool-chip interface showed that almost no fragments were found on the clearance face of the tool. The variation of wear with rake angle, depth of cut and cutting fluid were evaluated, and it was found that the amount of wear on the cutting face was of the same order of magnitude as that produced in a sliding experiment under analogous conditions. The friction values did not appear to be directly related to the variables of the cutting experiments and this, together with other experimental evidence, suggests that it is not possible to characterize the conditions during cutting by a single coefficient of friction.

Rheodynamic Squeeze-Film, The, by F. Osterle, A. Charnes & Dr. E. Saibel (Carnegie Institute of Technology). Considering grease as a Bingham plastic, the problem of the load supported by a squeeze-film is solved with grease as the lubricant. This load is found to depend on a single dimensionless parameter and to exceed the load which would be supported by a Newtonian fluid with the same mobility by an amount which approaches a constant as the squeeze velocity is increased.

Sliding Friction Test For Metalworking Lubricants, by W. J. Wojtowicz (H. A. Montgomery Co.). Lubricants used in drawing, stamping and forming may be evaluated by a simple sliding friction test. Measurements are made at slow speeds, 4 inches per minute, and moderate pressures, 5000 to 10,000 psi. Flow of metal is correlated with the average kinetic coefficient of friction; welding with a progressive increase of the friction force. Significant differences are observed when lubricants are tested on different metals. Aluminum, titanium, enamel stock, stainless, galvanized and cold roll steel have been investigated with lubricants such as: petroleum oils, chlorinated paraffins, waxes, dry soap films, and proprietary emulsions. The observed trends are consistent with conclusions derived from production tests as well as previous investigations. Anomalous behavior of lubricants, particularly dry films and chemical coatings, is discussed on basis of friction data.

Soluble Oil—Handle With Care, by A. A. Manteuffel (The Pure Oil Co.). Soluble oils are perhaps the most delicately balanced of the compounded industrial oils. Their wide acceptance in the metal cutting industry is well known and their beneficial effect in specific applications has been disclosed quite thoroughly. The fine quality product that reaches the consumer is the end result of careful compounding and handling. However, troubles can arise. This paper is intended to focus attention on those problems that can occur from the time of compounding to the time of application at the machine. Examples of potential trouble in the blend and in the emulsion are discussed in light of general known composition, and consideration is given to possible solutions.

Some Unusual Conditions Encountered In The Lubrication of Anti-Friction Bearings, by T. W. Morrison (SKF Industries, Inc.). In general, as long as the lubricant in an antifriction bearing maintains a satisfactory temperature, it will not affect the fatigue life of the bearing. However, with the use of synthetic lubricants and fluids, there is the possibility of reducing bearing endurance. Field experience and laboratory investigation have shown the necessity of maintaining an adequate oil film in anti-friction bearings. Under normal conditions this is not difficult, but at very slow speed, particularly under heavy load, special attention must be given to the viscosity.

Study Of Fretting Wear In Mineral Oil, A, by D. Godfrey (California Research Corp.; formerly with NACA, Lewis Flight Propulsion Laboratory). Experiments were conducted to determine the mechanism of and important factors of fretting in the presence of mineral oil. The results obtained with a hard steel ball vibrating in contact with a soft steel flat showed that in the first few cycles metal is transferred to the ball to cause galling, and the softer metal is scored and plowed. The damage increases with number of cycles. Wear fragments are generated at a constant rate and they accumulate in the oil surrounding the contact area until the oil is converted to a various mixture which is physically displaced from the contact area. From this point on fretting is "unlubricated" and brown films and cocoa colored debris appear. In unlubricated fretting the rate of wear is dependent upon the relative humidity of the surrounding air. Wear is a maximum at approximately 30 percent relative humidity. The physical properties of the debris change with humidity and apparently determine the rate of wear. In an investigation to evaluate lubricants for fretting it is important to keep out of the "unlubricated" state and to hold humidity constant. Runs with a few representative additives show that the effects of additives on fretting wear are similar to effects on wear with uni-directional sliding.

Study Of The Sliding Of Metals With Particular Reference To Atmosphere, A, by L. F. Coffin, Jr. (General Electric Co.). High temperature sodium or water, when used as heat transfer fluids in nuclear reactors, introduces many new problems in friction and wear since choice of materials becomes highly restrictive, and lubrication in the conventional sense does not exist. A fundamental understanding of the sliding process is required in order to attack these new problems. An experimental program is reported on the significance of some of the factors which have been found to affect the sliding characteristics of fairly pure elemental metals. As one consequence of this study, the strength of adhesion of mating asperities and the resulting frictional force and surface damage are found to be strongly dependent on the alloying ten-

dency of the metals of the sliding couple. The kind of gaseous atmosphere has a profound effect on the adhesion and sliding characteristics of these couples, the most striking change being found between inert gases such as argon and helium, and oxygen. Temperature is also found to be important, particularly in the sliding in various liquids of couples which alloy. Here a "transition" temperature is found in which the sliding characteristics and frictional force change abruptly as the temperature is lowered, from a condition of high friction and surface damage to one of low friction and damage. The process is found to be reversible.

Survey Of Wear Mechanisms, by J. T. Burwell, Jr. (Horizons, Inc.). A review is given of the several principal types of independent wear mechanisms which may be present, either simply or combined, in any particular wear situation. These include adhesive, cutting or abrasive, corrosive and surface fatigue as well as several minor types. The present state of our knowledge of each type is summarized and it is shown that we now have available quantitative semi-empirical relations for predicting the amount of wear in at least one and possibly as many as three of the types, and a relationship for the fourth is derived. These relations should also be useful for laying out and analyzing wear experiments.

Tool Weight Loss For Cutting Fluid Evaluation, by J. P. G. Beiswanger, J. P. Copes & R. L. Mayhew (General Aniline & Film Corp.). This paper describes a laboratory method for the evaluation of cutting fluids which is based on the fact that the loss in weight of a cutting tool, due to wear, can be measured directly by weighing the tool on a microbalance. This weight loss is followed as a function of the volume of metal removed from a work piece while using various cutting fluids under given cutting conditions of surface feet per minute, depth of cut feed, and tool-work pieces combination. The data, for the tool-work piece combinations studied when plotted on Cartesian coordinates, give a straight line function for tool weight loss (wear) versus volume of metal removed. The slope of this line is therefore the rate of tool wear. The relative efficiencies of fluid are judged then by their effect on decreasing or increasing this rate of wear.

Use Of A Glass Lubricant In The Extrusion Of Steel, by J. Sejournet & J. Delcroix (Comptoir d'Eirtage, France), presented by J. Strauss (Vanadium Corp.). Since 1941 glass has been developed as a high temperature lubricant to serve under great pressure in the extrusion of metals, particularly steel. Glass has excellent properties for that purpose: it is a poor conductor of heat, an undercooled liquid forming strong films at elevated temperatures. The following article shows, first the peculiarities of the extrusion process which makes it eminently suited for the production of complex shapes, and why it has long been desired to apply this method of forming to steel. Experiments and tests are described which led to the discovery of glass lubrication and thus made steel extrusion possible. The extrusion process and the type of friction encountered are then examined in detail. Difficulties in translating this process from a pilot operation to a full-scale industrial production process are described, e.g. that of finding a suitable glass at economic cost. Finally, the flow of metal at elevated temperatures with or without proper lubrication is studied, and the special properties of steel extruded under glass lubrication as well as examples of new products and applications are given.

Wear Of Iron In Sliding Contact With Various Elemental Metals, The, by C. L. Goodzeit, R. P. Hunnicutt & A. E. Roach (General Motors Corp.). This paper presents the results of an experimental investigation of the wear of iron in unlubricated sliding contact with thirty-nine different elemental metals. It was found that the wear process was associated with the transference of small particles of iron to the other metal. This occurred when the hardness of the other metal was the same or greater than that of iron. The

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wear of iron was not observed in the case of metals that were softer than iron.

Wear Studies With Radioactive Gears, by V. N. Borsoff (Shell Development Co.). Test equipment and methods used to detect and measure gear wear by radioactive techniques are described. Tests performed with unreactive mineral and synthetic oils, and also with lubricants containing extreme pressure additives show that three main types of wear exist in gears, namely: wear by scoring, wear by abrasion, and wear by chemical corrosion. These three types of wear are defined and discussed. The wear tests were supplemented with metal transfer studies which showed that metal transfer invariably occurs under scoring conditions but does not necessarily occur under conditions leading to light abrasion or chemical corrosion. The significance of metal transfer with respect to the mechanisms of lubrication and wear are discussed.

Worm Gear Reducers—Design & Operation, by R. B. Moir & S. D. Craine (W. A. Jones Foundry & Machine Co.). This paper will discuss from the users' viewpoint the revised ratings currently adopted by the worm gear manufacturing industry. The components which will be treated are: (1) the basic elements of the worm and gear; (2) the improvements that have been made justifying increased ratings; (3) the care in selection and mechanical operation of units; (4) the effects of the changes on the selection of lubricant; and (5) what the lubrication engineer and operating personnel should do to insure successful service from their worm gear units.

X-Ray Methods Applied To Automotive & Petroleum Research, by Dr. F. W. Lamb (Ethyl Corp.). This paper will present a brief review of the basic theory and principles of x-ray diffraction, x-ray fluorescence, and x-ray absorption. The particular advantages and limitations of these three analytical tools as well as their specific applications in the fields of automotive and petroleum research will be summarized. Major emphasis will be given to the applications made of x-ray diffraction in basic combustion and automotive engineering research projects. This will include a discussion of (1) the importance of knowing the true compound composition of materials, (2) the background work involved in preparing and characterizing some 90 or more complex lead salts by x-ray diffraction and thermal analysis, (3) solid-state reactions and their role in the formation of combustion products, and (4) spark plug studies resulting in a postulated mechanism of spark plug fouling.

(Men of Lubrication, from p. 85)

his serious contributions to mechanical engineering provide the most striking examples of his intellectual power. Unfortunately this list is too long to allow of more than passing mention of the more important accomplishments.

Reyonlds' work on the influence of air on rate of condensation is of fundamental importance in condenser operation, and his allied contribution to heat transfer in the "Reynolds' Analogy" is also of basic significance. His work on rolling friction was an original contribution in its field. His investigations in gas flow through nozzles had to some extent been anticipated. But the identification of throat velocity with the velocity of sound when the critical pressure ratio is reached or exceeded, explained why the discharge did not increase beyond this

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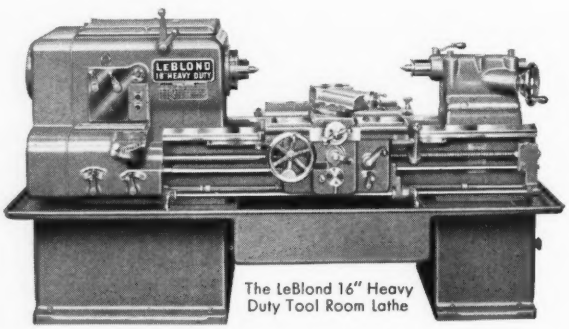

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point. This was an important addition to nozzle theory. Reynolds also was the first to apply guide vanes to pumps, and apparently the first to propose multistaging centrifugal pumps for high pressures. The use of guide vanes for hydraulic turbines was also invented by him at this time. At around the same period he seems to have built and tested a small steam turbine of the type afterwards developed by Sir Charles Parsons and which is essentially the steam turbine as we know it today. He did not carry this further apparently because of its poor efficiency due to high clearance losses. Experience has not supported this view. The clearance losses do not remain a constant fraction of the power as size is increased, and Reynolds missed giving this great invention to the world.

Reynolds also made a number of consequential contributions in the realm of pure physics and his magnum opus, "On the Sub-Mechanics of the Universe," was in this field. The work fills the entire third volume of his collected papers. It has been kindly dealt with by Horace Lamb in his obituary notice of Reynolds, but it does not seem to have been accepted by mathematical physicists as a satisfactory theory of matter.

In spite of an extraordinary ability to realize the importance of a problem and to apply the logical methods of science to its elucidation, Reynolds was not a good teacher. His classroom lectures were apparently given in a very erratic manner and in many cases at a level much beyond the capacity of his students. This tendency to be abstruse is carried into his more technical writing making him a rather difficult author. In later life this lack of clarity became, due to failing health, much worse until finally he was forced to retire in 1905. He died in 1912.

Reynolds was not an equal of the great luminaries of British science of his period. Men such as Kelvin, Stokes, and Rayleigh were very definitely in a higher intellectual echelon. He had their same Cambridge background but made his contributions in engineering rather than physics. He was at one time an applicant for the chair of experimental physics at Cambridge. His candidacy was, however, unsuccessful and the appointment went to his former student, J. J. Thomson (afterward Sir J. J. Thomson), who later discovered the electron and directed research at the Cavendish laboratory (Cambridge) into the rewarding field of atomic physics. One wonders what different course physics might have taken if Reynolds had been elected to the chair. To his associates he was held in veneration, as well he might with such accomplishment to his credit. He was elected a fellow of the Royal Society in 1877.

In 1919, Albert Kingsbury founded the Osborne Reynolds Research Fellowship in Engineering at Manchester University, "as some recognition of the debt which he owed to Reynolds' researches in lubrication" — an appropriate memorial to this great man of science.

ACKNOWLEDGMENTS. The main sources consulted in the preparation of this article are: "Osborne Reynolds," by A. H. Gibson (a publication of the British Council); obituary notice of Reynolds by Sir Horace Lamb; Proceedings of Royal Society of London, Series A 1913; and Reynolds' Collected Papers.

(Lube Lines, from p. 71)

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service are charged (rates available upon request from ESPS). Note initial listing of this service in this issue of **Lubrication Engineering.**

AMENDMENT. ("The Reaction of Adsorbed Stearic Acid with Copper & Copper Oxide," by A. Dobry, **Lubrication Engineering,** Vol. 10, No. 4, 1954.) Page 211, 2nd column, 1st paragraph, 5th sentence, should read: "The combined acid extracts from each coil were then analyzed for copper by neutralizing to pH 9 with concentrated ammonium hydroxide, adding 5 ml. of 10% aqueous ammonium citrate, diluting to 25 ml., adding 1.0 ml. of 0.1% aqueous sodium diethyldithiocarbamate solution, and extracting for exactly two minutes with 5 ml. of reagent grade CCl_4.[6]"

(Personals, from p. 96)

Indiana, Inc. Announcement of the change came from the parent company, Houdaille-Hershey Corp., Detroit.

J. L. Duchene, Baldwin-Lima-Hamilton Corp., has been appointed Sales Engineer for iron and bronze foundry products in western Pennsylvania, with offices at 567 Union Trust Bldg., Pittsburgh.

E. F. Houghton & Co., Philadelphia, announce the following appointments: **Dr. J. T. Eaton,** as Vice-President, Production; **Dr. K. C. Frisch,** Assistant Manager of Research; and **Dr. E. Abrams,** as Supervisor of Organic Research.

R. M. Hammes has been named General Sales Manager of the Niagara Filters Div. and the Tolhurst Centrifugals Div. of American Machine & Metals, Inc., East Moline, Ill.

The Brooks Oil Co. announces the following appointments: **F. H. McCurdy, Jr.,** as Chicago District Manager; **T. M. Stonerod,** as General Sales Manager, and **A. A. Paul,** as Manager of Service (Hq., Pittsburgh).

R. G. Keppler has been appointed Technical Sales Representative for the Refinery Chemicals Dept. of American Cyanamid Co., with offices in Houston, Texas.

The Briggs Filtration Co., Washington, D. C., announces the appointments of the following Industrial Sales Representatives: **F. Lewis,** western New York and northwestern Pennsylvania area (Hq., 1807 Elmwood Ave., Buffalo 7); and **H. D. Urdanoff,** northern New Jersey and eastern Connecticut area (Hq., Bowser, Inc., 420 Lexington Ave., N. Y. 17).

Air-Maze Corp., Cleveland, has named **B. W. Carkin** as Sales Engineer of Railroad & Original Equipment Installations, and **B. T. Church** as Manager of Distributor Sales.

Copies of "The Maintenance in Service of Lubricating Oil Quality by Filtering, Centrifug-

ing, Reclamation," by **W. C. Bauer** (presented at a recent ASLE Chicago Section meeting) may be obtained by writing: The Briggs Filtration Co., River Rd., Washington, D. C.

(Current Literature, from p. 90)

ing devices, filter media, textile fibers for filtration, a comprehensive chart on chemical and heat resistance of cotton and synthetic fabrics, sections on yarns, fabric construction and finishing, and a roundup of filter fabrics in use. (Wellington Sears Co., 65 Worth St., N. Y. C.)

Molykote Lubricants Field Reports. Field Reports 136 & 138, covering the lubrication of office machinery parts and sub-assemblies, and typical particle sizes of molybdenum disulfide products, have been recently released. Replete with illustrations, Field Report 136 shows in detail a few of the friction parts which one manufacturer of office machinery coats with Molykote during assembly. Field Report 138 uses micro-photographs to show comparative particle sizes of various grades of Molykote lubricants. (The Alpha Corp., 65 Harvard Ave., Stamford, Conn.)

Oil-Rite Electro Oilers. Bulletins 68-70 & 102 describe the application, operation, and construction, and a problem-solution-results case history, respectively, of Electro Oilers — oilers entirely automatic in operation, designed to eliminate bearing failures, reduce oil consumption to a minimum, and provide controlled lubrication to multiple points. (Oil-Rite Corp., 2318 Waldo Blvd., Manitowoc, Wisc.)

"Houghto-Safe for Steel Mills." Because of the many applications in the steel industry where use of a fire resistant hydraulic fluid is imperative for safety reasons, a special leaflet on the subject has been published listing the physical properties, advantages, installation data and typical applications for Houghto-Safe non-flammable hydraulic fluid. Emphasized are the lubricity and oxidation stability properties of this

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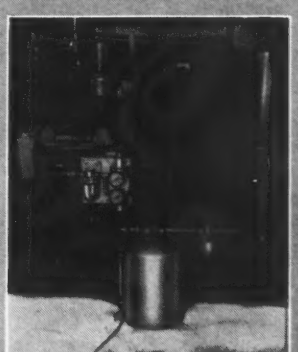

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Garlock O-Ring Catalog, AD-148. A complete catalog describing Garlock O-Rings has been released giving complete design information, recommended pressures, and available materials for both "dynamic" and "static" applications. (The Garlock Packing Co., Palmyra, N. Y.)

"Filter Facts No. 1, Fundamentals of Filtration." 'Color is no indication of oil condition.' This is just one of many interesting facts set forth in a new 12-page engineering paper, the first of a series based on factual engineering data concerning filter facts. (Engine Life Products Corp., El Monte, Calif.)

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(Section News, from p. 109)

& Bearings from the Metallurgical Viewpoint," covering design, choice of materials, and the importance of research and experience.

February & March. Lubrication Course conducted at Dunwoody Industrial Institute, with speakers and their subjects as follows: A. A. Raimondi, Westinghouse Electric Corp., "Principles of Lubrication;" C. A. Bailey, U. S. Steel Corp., "Properties of Lubricants;" M. L. Carter & R. Jolley, Southwest Grease & Oil Co., Inc., "Greases for Industrial Use;" W. T. Everitt, Eastman Kodak Co., "Application of Lubricants;" G. B. Miller, Racine Hydraulic & Machinery Co., "Hydraulic Oils & Hydraulic Machinery;" D. F. Wilcock, General Electric Co., "Anti-Friction Bearings;" W. H. Ragborg, Dow-Corning Corp., "Synthetic Lubricants;" E. S. Johnson, Imperial Distributors, "Solid Lubricants;" T. E. Knoertzer, The Texas Co., "Analysis of Failures;" R. O. Bartels, Socony-Vacuum Oil Co., "Proper Purchasing, Storage & Handling of Lubricants." (Submitted by C. D. Johnson, Sec'y.)

(New Products, from p. 100)

tures. Hot or cold, the indicating hand points only to true and permanent changes. (Booklet 800, The Gerin Corp., Avon, N. J.)

Norgren 33AB-4 Lubrication Unit. A new, large-capacity bearing lubrication unit of the oil-fog type has been announced offering unique automatic control features. Of 4½ gallon oil capacity, and using twin lubricator heads (which may be used simultaneously or individually, depending on fog requirements for the specific application), the fine Micro-Fog generated can be carried great distances with a minimum of precipitation in the lines and can be uniformly distributed to multiple bearing lubrication points having a maximum total of 1000 bearing inches. Measuring 27" x 12½" x 16½", three 2" fog outlets provide for flexibility of installation. A system of automatic controls provides warning

signals or other safeguards against depletion of oil supply, failure of air supply, excessive pressure in oil supply tank; Micro-Fog delivery automatically starts and stops in coordination with the machine operation. (Bulletin 492-A, C. A. Norgren Co., 3434 S. Elati St., Englewood, Colo.)

"Houghton Pickling Inhibitors." Two new pickling aids, plus an improved version of an established heavy-duty inhibitor, are described in a new bulletin. Acitrol 3129, an improved non-foaming heavy-duty inhibitor now effective over a wider range of conditions, needs no pre-mixing, offers high stability, and maintains its effectiveness over extended periods of use or storage. The polar activity feature assures maximum speed and efficiency even at temperatures in excess of 180 F. Acitrol 3130 is a new, foam producing pickling inhibitor which produces clean, smut-free surfaces and is especially useful where bright work is desired. The high wetting out and detergency ability, plus its foaming action, increase pickling speed and minimize drag-out losses; its efficiency at temperatures much below those normally used provide lower heating costs and less possibility of metal attack. Acitrol Foam 25 is a completely new cationic foam-producing chemical which can be used in any desired concentration to provide various foaming action. It produces a dense, continuous foam blanket which is free of all sludge-like contaminants. By its superior wetting action, it assures fast acid penetration into the scale layer and promotes speedy rinsing. (E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.)

Model 6-PA-6 Ferrofilter. For the magnetic filtration of lubricating oil in heavy machinery, a new magnetic separator has been produced that contains in one shell six permanent magnet separator assemblies. Each assembly comprises a stack of thirteen grids graded as to openings, strongly magnetized by a pair of Alnico permanent magnets. The grids are of honeycomb design, and split the oil into thin streams forcing vagrant particles of steel, iron, rust, and scale to pass close to thousands of feet of strongly magnetized grid edges. Here the strongly convergent magnetic fields create intense forces on even the finest magnetic particles, attracting them to the grids and holding them until the Ferrofilter is cleaned. Model 6-PA-6 is made with 8" flanged inlet and outlet pipe connections and has a rated capacity of 450 gpm for oil of 2500 SSU viscosity. For oils of lower viscosity, its capacity ranges up to 1200 gpm. Because the grids offer little resistance to the flow, the pressure drop is held to 2.5 psi. (S. G. Frantz Co., Inc., Trenton, N. J.)

Redesigned Dual Titrometer. Developed in cooperation with Shell Development Co., and originally intended for the determination of acidity in lubricants, the Dual Titrometer has been redesigned to provide greater sensitivity, wider range, and easier operation. Applicable to a wide range of other opaque and highly colored solu-

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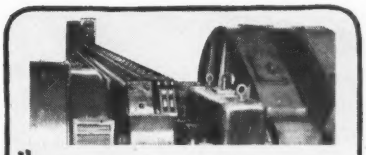

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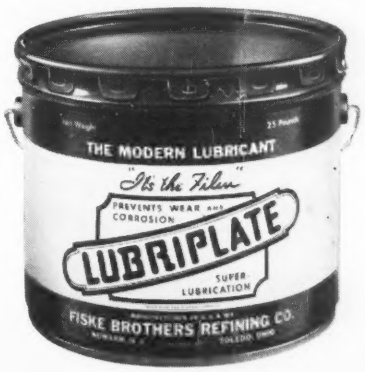

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Lubrication in the News

Fog Application of Cutting Fluids Studied. Because of the widespread and increasing interest in the application of cutting fluids as a fog or mist and the dearth of factual information on the subject, the ASTE Research Fund Committee is sponsoring an investigation into such applications. Objectives of this research project are to determine the advantages and limitations of the method, obtain representative metal cutting performance data, outline fields for further study as indicated by the results of the project and explain indicated results in terms of current theories on fog application.

Initial phase of the project will be a survey of the literature covering uses of fogs as applied to cutting tools and bearings, and as used in heat transfer generally. Since valuable information has been published on each of these applications independently, it is assumed that a compilation of the known information will provide new keys to the physical, cooling and lubricating effects of mists and fogs.

Laboratory tests will be conducted in such a manner that the data obtained will be directly comparable to results obtained with more conventional methods of applying cutting fluids. Controlled variables in the investigation will be: workpiece material, cutting speed, feed, depth of cut, tool material and configuration, and types of cutting fluids and additives used with continuous and intermittent cuts. Methods of, and equipment for, generating fogs will also be studied. Uncontrolled variables that will be measured include: tool life, workpiece surface finish, forces generated, temperatures induced and power required.

The current project resulted from a proposal by the Machine Tool and Metal Cutting Laboratories of Massachusetts Institute of Technology. Trained personnel of the laboratories will perform the necessary investigations, follow through the analysis and prepare a report. Work will be under the guidance of a Research Fund Steering Committee comprising: F. E. Anderson, Pres., F. E. Anderson Oil Co., Inc.; R. B. Boswell, Research Dept., Engrg.

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Div., Chrysler Corp.; W. E. Kramer, Head, Industrial Engrg. Div., Gulf Research & Development Co.; and G. Swardenski, Ass't. Factory Mgr., Caterpillar Tractor Co.

Patent Abstracts

This feature is compiled by Ann Burchick, Aluminum Compnay of America.

Castor Oil Lubricating Composition, Patent No. 2,692,858 (E. A. Evans & J. S. Elliott, assignors to C. C. Wakefield & Co., Ltd.) A lubricating composition comprising a major proportion of castor oil in which is incorporated a proportion of from 0.05% to 2.0% of a metallic organic compound soluble in caster oil and selected from the group consisting of tin and antimony salts of aliphatic mono-carboxylic acids having 12 to 18 carbon atoms, organic sulphonic acids, naphthenic acids, and phenol thioethers and a proportion of from 0.1% to 5.0% of an aromatic secondary amine containing at least three cyclic nuclei, at least two of which nuclei are aromatic nuclei attached directly to the nitrogen atom.

Metal Working Lubricant, Patent No. 2,692,859 (S. K. Talley, S. J. Beaubien & L. P. Richardson, assignors to Shell Development Co.) A metal working lubricating composition comprising a major amount of water and a minor amount of from 0.01 to 10% each of alkyl phenol-ethylene oxide reaction product, a nitrite selected from the group consisting of an alkali metal nitrite and an organic nitrogen base nitrite and an inorganic alkali metal phosphate.

Demulsified Antirust Turbine Oil, Patent No. 2,693,448 (P. S. Landis, H. D. Norris & R. V. White, assignors to Socony-Vacuum Oil Co., Inc.) A solvent-refined turbine oil having a viscosity of between about 350 seconds and about 600 seconds Saybolt at 100 F. containing (1) between about 0.05 and about 2%, by weight, of a phenolic anti-oxidant; (2) between about 0.01% and about 10%, by weight, of an antirust agent which is the reaction product obtained by reacting oleic acid with triethylenetetramine, in a molar proportion of between about 3:1, respectively, and about 1:1, respectively, to produce an intermediate product and reacting an alkenyl succinic acid anhydride with said intermediate product, in a molar proportion of between about 1:1, respectively, and about 3:1, respectively, the number of moles of said

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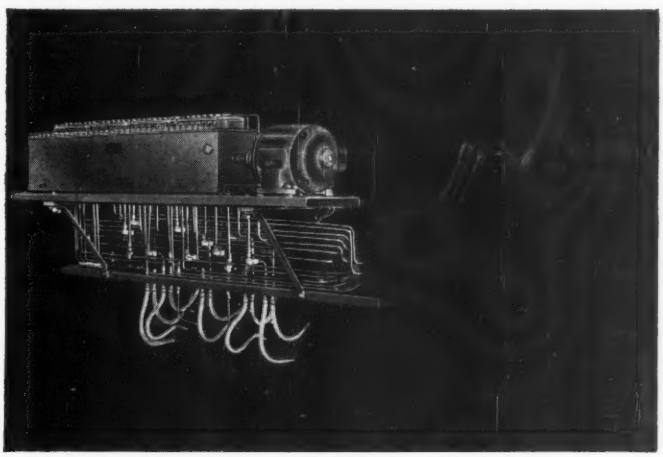

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oleic acid and of said alkenyl succinic acid anhydride reacted with each mole of said triethylenetetramine being no greater than 4; and (3) between about 5% and about 25%, by weight, based upon the weight concentration of said antirust agent, of a demulsifier selected from the group consisting of petroleum sulfonic acids, ammonium salts of petroleum sulfonic acids and metal salts of petroleum sulfonic acids wherein the metal thereof is selected from groups I, II and III of the periodic table.

Silicone Greases, Patent No. 2,693,449 (G. M. Hain & W. A. Zisman.) A lubricating grease comprising a major amount of an organo-silicon polymer fluid, a minor amount of a lithium soap sufficient to thicken the fluid to a grease consistency and a minor amount of phenothiazine sufficient to increase the oxidation resistance of the grease.

Wire Rope Lubricant Comprising a Blown Residuum, a Petroleum Wax, and a Light Chlorinated Hydrocarbon, Patent No. 2,693,450 (R. F. Nelson, assignor to The Texas Co.) A wire rope lubricant consisting essentially of a blown petroleum residium from a paraffinic crude oil as the predominant constituent, about 5-15% by weight of petroleum and about 5-25% by weight of a light chlorinated aliphatic hydrocarbon having a boiling point within the range of about 125-210 F., said lubricant having an ASTM unworked penetration in the range of about 120-150 F.

Stabilization of Phosphosulfurized Hydrocarbons, Patent No. 2,694,044 (F. B. Fischl & E. B. Cyphers, assignors to Standard Oil Development Co.) An additive compostion for lubricants comprising a major portion of a phosphosulfurized, substantially non-olefinic hydrocarbon and stabilizing amounts of an ester of an aliphatic acid having less than about 6 carbon atoms and a monohydric, unsaturated alcohol having at least 2 and less than 10 carbon atoms, said amounts being sufficient to stabilize the material against substantial evolution of sulfur containing gases.

Stabilizer for Petroleum Products, Patent No. 2,694,045 (A. R. Jones & J. O. Smith, Jr., assignors to Standard Oil Development Co.) A composition consisting essentially of a major amount of a mineral oil susceptible to oxidation and a minor amount sufficient to inhibit oxidation, of the thiocyanate derivative of a product obtained by reacting a compound selected from the group consisting of pyridine, picolines, lutidines and quinoline with an aryl sulfonyl halide substantially at room temperature to form an addition product wherein the halogen radical of said addition product is replaced by the NCS-radical.

Lubricating Oil Composition, Patent No. 2,694,046 (A. Dorinson, assignor to Sinclair Refining Co.) A lubricating oil composition which comprises a mineral

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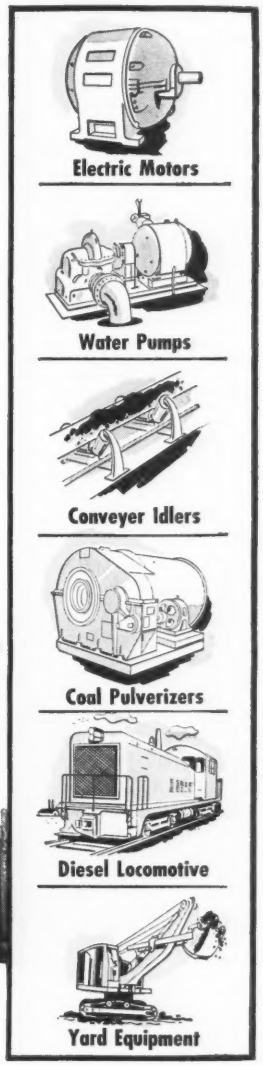

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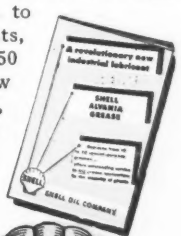

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lubricating oil having incorporated therein about 0.5 to about 4 weight per cent of the product formed by the reaction of about 45 parts of sulfur monochloride and a mixture comprising about 100 parts of alpha-pinene and about 100 parts of oleic acid at a temperature of about 140 to 158 F.

Lubricating Grease Containing Pectic Acid Salt, Patent No. 2,694,683 (A. J. Morway & L. A. Mikeska, assignors to Standard Oil Development Co.) A lubricating grease comprising about 60-98 wt. percent lubricating oil and about 2-40 wt. percent of a grease thickener, of an alkali metal salt of pectic acid, the remainder of said thickener comprising an alkali metal soap of a high molecular weight fatty acid having 18-22 carbon atoms and an alkali metal salt of a low molecular weight carboxylic acid having 1-5 carbon atoms, the mol ratio of low molecular weight acid salt to high molecular weight fatty soap plus pectic acid soap being 1-3.

Maleinoid-Vinyl Copolymer and Its Use in Lubricants, Patent No. 2,694,685 (J. H. Bartlett, assignor to Standard Oil Development Co.) A lubricating oil composition comprising a major proportion of a lubricating oil and a small amount, sufficient to depress the pour point thereof, of an oil-soluble copolymer of a vinyl ester of a fatty acid having from 2 to 18 carbon atoms and a dialkyl maleate wherein each alkyl group ranges from not less than 10 to not more than 18 carbon atoms.

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Production of Low Aniline Point Oil, Patent No. 2,695,262 (E. V. Mathy, assignor to Phillips Petroleum Co.) A process for producing a hydrocarbon product having a predetermined aniline point lower than the aniline point of the feed stock from which it is produced and in greater yield than is obtained by solvent extracting the entire hydrocarbon feed stock to said predetermined aniline point for use in the manufacture of a furnace carbon black and for the production of a paraffinic oil which comprises, dividing a gas oil feed stock of aniline point within the range of 125 to 160° F., and boiling within the range of 450 to 750° F., into two portions, each portion having said aniline point range and said boiling point range, solvent extracting one portion of said gas oil with a solvent preferential to aromatic hydrocarbons to an aniline point of —75 to 25 F., the volume ratio of said solvent to said one portion of said gas oil being in the range of 0.5:1 to 5:1, carrying out this extraction operation at a temperature within the range of 50 to 160 F., from this extraction operation separating an aromatic hydrocarbon oil rich phase and a paraffinic hydrocarbon oil rich phase, separating solvent from each of said phases and recycling the separated solvent to the extraction operation, recovering the solvent-free paraffinic hydrocarbon oil as a paraffinic gas oil, admixing the solvent-free aromatic hydrocarbon oil with the other portion of said gas oil feed stock and recovering this admixture as said hydrocarbon product having a predetermined aniline point lower than the aniline point of the feed stock from which it is produced and in a greater yield.

Method of Treating Hydrocarbon Base Lubricants with a Phosphorus Sulfide in the Presence of Butyl Rubber & Product, Patent No. 2,695,271 (E. C. Hughes, H. E. Alford & J. D. Bartleson, assignors to The Standard Oil Co.) A method of processing hydrocarbon lubricating oil stock which method comprises treating said stock with an amount of phosphorus pentasulfide in the range of about 0.1 to about 0.75% at a temperature in the range of about 275 to about 450 F. in the presence of a small amount within the range from about 0.25 to 2% of butyl rubber.

Soluble Metalworking Oil, Patent No. 2,695,272 (L. F. King & L. W. Sproule, assignors to Standard Oil Development Co.) A soluble metalworking lubricant composition comprising a mineral base lubricating oil, 2 to 7% by weight, based on the total composition, of oil soluble sodium sulphonate, and supplementary soaps including 1 to 5% of an alkylolamine salt of napthenic acid and 3 to 8% of an alkylol amine soap of tall oil.

Lubricating Oil Compositions, Patent No. 2,695,273 (E. O. Hook & W. D. Thomas, Jr., assignors to American Cyanamid Co.) A hydrocarbon lubricat-

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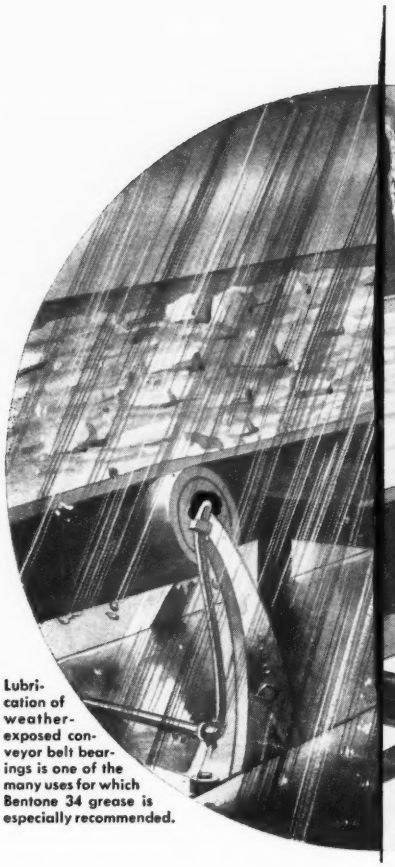

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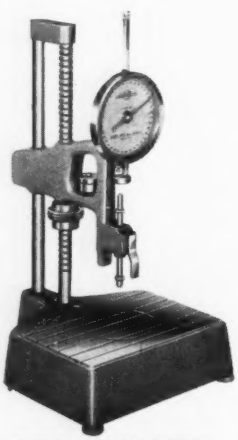

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ing oil composition comprising a major proportion of a hydrocarbon lubricating oil, from about 0.01% to about 3% by weight of 2,2'methylene bis (4-methyl-6-tertiary butyl phenol), and a basic petroleum sulfonate of a metal selected from the group consisting of alkaline earth metals and heavy metals in an amount sufficient to reduce the lacquer-forming propensities of the hydrocarbon lubricating oil composition.

Water-in-Oil Soluble Oil, Patent No. 2,695,877 (C. W. Nichols, Jr. & H. J. Schroeder, assigner to Socony-Vacuum Oil Co., Inc.) A soluble oil comprising: about 5% by weight of neutral degras; about 1% by weight of di(glycolmonooleate) malate; about 0.5% by weight of oleyl acid phosphate; about 2.5% by weight of chlorinated hydrocarbon having a chlorine content of 42% by weight; and 1.5% by weight of aluminum stearate; about 2% by weight of a fatty acid ester of a hexitol anhydride, said fatty acid having at least six carbon atoms; about 2% by weight of a polyoxyalkylene derivative of a fatty acid ester of a hexitol anhydride, said fatty acid having at least six carbon atoms; and the balance, to make 100%, mineral lubricating oil.

Greases Containing a Lithium Soap of Polymerized 12-Hydroxy Stearic Acid and Their Method of Manufacture, Patent No. 2,695,878 (G. Entwistle, assignor to Sinclair Refining Co.) A lithium soap grease consisting essentially of a lubricating mineral oil thickened at a maximum temperature of about 300 F. to 330 F. to grease consistency with a soap formed at a temperature of about 170 to 250 F., of a lithium base and polymerized 12-hydroxy stearic acid, the polymerized 12-hydroxy stearic acid being prepared by heating 12-hydroxy stearic acid to about 150 to 300 F. for a period of time sufficient to reach substantial equilibrium and the lithium base being present in an amount sufficient to saponify the acid.

Antifoamant Composition, Patent No. 2,695,879 (J. A. Jehle, Jr., assignor to Socony-Vacuum Oil Co., Inc.) A mineral lubricating oil containing between about 0.1% and aobut 1.5%, by weight, of an antifoamant composition consisting of between about 2% and about 30%, by weight, of an ester selected from the group consisting of aliphatic monoesters of sorbitol anhydrides and aliphatic monoesters of polyoxyethylene derivatives of sorbitol anhydrides, and between about 98% and about 70%, by weight, of the reaction product formed by reacting about 3 moles of an alkyl phenol having a total of between about 8 carbon atoms and about 12 carbon atoms in the alkyl radicals thereof, with about 1 mole of phosphorus pentoxide, at a temperature of between about 75 C. and about 125 C.

Telomer Greases, Patent No. 2,695,880 (A. F. Benning & F. B. Hill, Jr., assignors to E. I. duPont deNemours & Co.) A grease having a high viscosity index comprising an intimate homogeneous mixture of (1) 70% to 90% by weight of a telomer oil boiling above 70 C. at 10 mm., selected from the class consisting chloroform telomers of monochylorotrifluorothylene, carbon tetrachloride telomers of monochlorotrifluoroethylene, chloroform intertelomers of monochlorotrifluorethylene and tetrafluorothylene, carbon tetrachloride intertelomers of monochlorotrifluorethylene and tetrafluoroethylene, and mixtures of the said telomers, the terminal halogen of the said telomers, the terminal halogen of the telomer oil being selected from the group consisting of chlorine and fluorine; and (2) 10% to 30% by weight of a telomer thickener having a molecular weight of between about 2500 and 4000 selected from the class of chloroform telomers of tetrafluoroethylene and carbon tetrachloride telomers of tetrafluoroethelene.

Conductive Oil-Base Drilling Fluids, Patent No. 2,696,468 (P. W. Fischer, assignor to Union Oil Co. of California.) The method of preparing an electrically conductive oil-base drilling fluid which comprises adding to a normally non-conductive oil-base drilling fluid between about 5 and about 20% by weight of a composition comprising 100 parts by weight of water, between about 10 and about 40 parts by weight of a mixture of an alkali-metal hy-

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droxide and water-soluable salt of a strong base and a weak acid, and between about 20 and about 80 parts by weight of an emulsifying agent selected from the class consisting of sulfated oils, sulfated alcohols, aliphatic and naphthenic sulfonates, aromatic sulfonates, and the alkali-metal salts thereof.

Carbon Black Lubricating Grease, Patent No. 2,696,469 (Rosemary O'Halloran, assignor to Standard Oil Development Co.) A lubricating grease comprising a major proportion of mineral lubricating oil thickened to a grease consistency with a combination of 3-30% by weight, based on total grease, of carbon black and 1.5-10% by weight, based on total grease of aluminum soap, said carbon black having a surface pH value not greater than 5.0 an average particle diameter below about 20 microns and a volatile matter content of at least 5% by weigh, said grease containing about 6-15% by weight, based on total grease, of an extreme pressure additive composed essentially of about 5-10% by weight, based on total grease, of sulfurized sperm oil, about 1-5% by weight, based on total grease, of sulfurized sperm oil, about 1-5% by weight, based on total grease, of a free high molecular weight fatty acid and about 0.1-2% by weight, based on total grease, of an oil-soluble phosphate ester selected from the group consisting of tricresyl and tributyl phosphates, said sulfurized sperm oil, fatty acid and phosphate ester being present in a weight ratio of about 9:2:0.5-1, respectively.

Lubricating Greases Thickened with Carbon Black, Patent No. 2,696,470 (J. J. Kolfenbach & H. G. Vesterdal, assignors to Standard Oil Development Co.) The process of preparing a lubricating grease which comprises forming a thin soap grease by cooking 1% to less than 5% bq weight, based on finished grease, of a metal soap of C_{18} to C_{22} substantially saturated fatty acids with a metal selected from the group consisting of the alkali, alkaline earth metals and aluminum in a grease-forming lubricating oil at a soap-forming temperature, adding 4.5-15% by weight, but more than said soap, of reticulate particle carbon black of high oil absorptive properties, heating the mixture so formed to a temperature sufficiently high to maintain the soap in the liquid state, mechanically working the mixture to obtain a high degree of soap coating on the carbon black, and cooling to obtain a stable grease structure.

Carbon Black Lubricating Grease, Patent No. 2,696,471 (Rosemary O'Halloran, assignor to Standard Oil Development Co.) A lubricating grease composition comprising a major proportion of acid treated petroleum base lubricating oil, 1 to 5% by weight, based on the total composition, of aluminum soap of predominantly saturated fatty acids of the C_{12} to C_{22}

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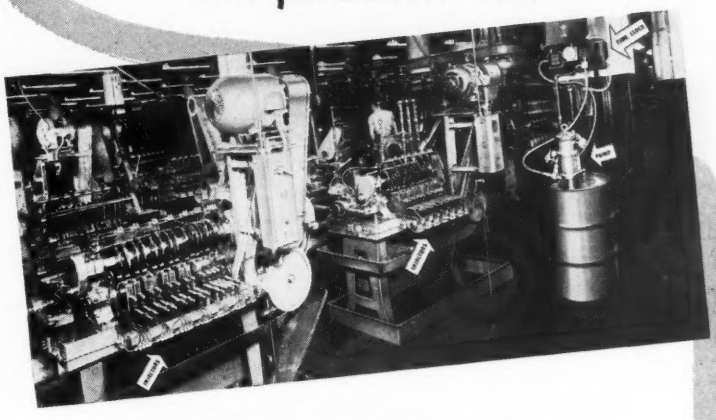

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range, 5 to 25% of carbon black, 0.5 to 4% of saturated fatty acid of the C_{14} to C_{20} range, and 5 to 15% of a sulfurized fatty oil as an extreme pressure agent.

Corrosion Inhibited Lubricating Oil, Patent No. 2,696,472 (J. M. Butler, assignor to Monsanto Chemical Co.) A lubricating oil composition comprising a major amount of a mineral lubricating oil and from about 0.1 to about 5 parts by weight per 100 parts by weight of the mineral lubricating oil of a (tert-alkylmercapto)-zinc N,N-dialkyl dithiocarbamate antioxidant.

Halogen Containing Extreme Pressure Lubricant Stabilized with a Polyalkylene Polyamine, Patent No. 2,696,473 (S. J. Sokol, deceased, by H. Sokol, administrator, assignor to The Texas Co.) A lubricant composition consisting essentially of a hydrocarbon lubricating oil as the major component, containing a minor amount of an oil-soluble organic halogen containing compound having extreme pressure properties and which is normally corrosive to metals at elevated temperatures and pressures, a minor amount sufficient to impart improved load carrying properties to the said composition of a lead soap, and about 0.01 to about 1% by weight of a polyalkylene polyamine represented by the general formula

$$NH_2R(NHR)_xNH_2,$$

where R is an ethylene group and x is an integer from 1 to 4.

Coming Events

MAY

1-4, American Institute of Chemical Engineers, Shamrock Hotel, Houston, Tex.

14-22, World Wide Chemical Plant & Equipment Exposition & Congress, Frankfurt, Germany.

16-18, American Petroleum Institute (Division of Marketing, Lubrication Committee), The Greenbrier Hotel, White Sulphur Springs, W. Va.

30 thru June 1, Chemical Institute of Canada (38th Annual Conference & Exhibition), Quebec City, Canada.

JUNE

6-15, Fourth World Petroleum Congress, Rome, Italy.

12-17, SAE Golden Anniversary (Summer meeting), Chalfonte Haddon Hall, Atlantic City, N. J.

20-23, American Society of Mechanical Engineers (semiannual meeting), Statler Hotel, Boston, Mass.

OCTOBER

27-28, National Conference on Industrial Hydraulics (11th Annual meeting), LaSalle Hotel, Chicago, Ill.

8 W. 40th St.....New York City
100 Farnsworth Ave.....Detroit
84 E. Randolph St.....Chicago
57 Post St.....San Francisco

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A weekly ESPS bulletin of positions open is available by subscription (rates on request).

Direct all correspondence to: ESPS, Inc., at one of the addresses listed above.

ENGINEERS AVAILABLE

Ind. Mgmt. (132-LE) 41, Org. & Phys. Chem.; 10 yrs. corrosion specialist & metallurgist in stainless steels, aluminum; 9 yrs. materials of constr., supervision, plant problems, laboratory supv.; Midwest; $10,000.

Mech. Engr. (133-LE) 44, ME; 22 yrs. resp. charge of operation, maintenance, lubr., & personnel of power plants, boilers plants; Midwest; $8,500.

Geologist (134-LE) 25, Geogology; 22 mos. iron, copper, sulfur, sand & gravel exploration; prefer geological or geophysical work in petroleum ind.; U. S.; $4,800.

Designer (135-LE) 27, ME; 1½ yrs. drafting, simple design work & machine shop exp.; 2 yrs. design of tools, jigs, & fixtures; 16 mos. in plant engineering handling preventive maintenance with oil company; Midwest; $6,600.

Gen. Mgr. (136-LE) 59, Mine Engrg.; 10 yrs. adm. and personnel work for Bureau of Mines; 12 yrs. industrial sales of petroleum products; U. S.; $10,000.

Petr. Engr. (137-LE) 43, ME; 4 yrs. resp. for info. concerning lubrication requirements of ind. eqpt.; 3 yrs, resp. for quality of metal working products; 4 yrs. sales & application of lubricants, fuels & other petroleum products; Chicago; $10,200.

Maint. Engr. (138-LE) 39, ME, 6½ yrs. made lubrication survey, guided maintenance, inspections & set up modern lubrication procedures; 4½ yrs. designing & supervising of paper & other special machinery; Midwest; $7,000.

Mach. Design (139-LE) 43, ME; 10 yrs. layout & design of paper mill machinery & improvements & gas turbines; 1½ yrs. design staff lubr. engr.; Midwest; $6,000.

Gen. Mgr. (140-LE) 39, Ch.E.; 1 yr. managing sand & vapor cleaning & furniture refinishing co.; 2 yrs. owner & salesman of synthetic lubricants, petroleum additives & fuels; 9 yrs. selling heat transfer eqpt.; U. S.; $7,500.

Marine Engr. (141-LE) 26; 3 yrs. marine engineer for refining company; Midwest; $7,000.

Ch. Engr. (142-LE) 47, CE; 7 yrs. directed, supervised construction of steel mill & refinery installation; 2½ yrs. construction supt. for oil refinery; 2 yrs. charge of constr. of gas plant; Midwest; $8,000.

Field Engr. (143-LE) 30; 1 yr. party chief making surveys of land, highways, sewage systems & designing subdivisions (ran 2 parties, had all layout, inspection, heat expansion records); 1 yr. drawings & checking others on piping of oil refineries; 5 yrs. draftsman doing all phases of field work for oil refinery; Midwest; $6,500.

Prod. Engr. (144-LE) 34, AB; 5 yrs. doing local administration; 1 yr. service engr. on drilling supplies; 2 yrs. road constructing & material testing; 1 yr. electrical geophysical exploration; 3 yrs. shift supervisor of refinery laboratories; U. S.; $6,500.

Proj. Engr. (145-LE) 33, ME-EE; 4 yrs. proj. work handling mech. &' elec. design of mining & chem. plants; 13 mos. layout & design of mechanical eqpt. in hydro-electric power plants; 1 yr. maintenance & operation of mechanical eqpt. in steam power plant; 2 yrs. machine design, preliminary layout & drafting; Midwest; $7,500.

Sales Mgr. (146-LE) 47, Chem. & Bio. Science; 15 yrs. directing sales of agricultural chemicals & feeds; 2 yrs. consulting in same field; 3 yrs. research & atomic production eqpt.; Midwest; $7,500.

Sales (147-LE) 50, ME; 9 yrs. export sales of electronic & automotive products; 2 yrs. conducting endurance test runs in engine lab.; 2 yrs. resp. for contracts covering manuf. of gasoline & diesel engines; 14 yrs. charge of projects in drafting room covering erection of apt. bldgs.; U. S.; $7,200.

Chem. Engr. (148-LE) 35, MS, Chem. Engr.; 3½ yrs, charge of pre-pilot plant engrg. studies; 2 yrs. research petr. products particularly relating to gasoline engines.

Chief Engr. (149-LE) 28, CE; 10 mos. resp. for engrg. dept. of steel works; 9 mos. draw plans for grading layouts of gas meter sites for pipe line; 3 yrs. design & drawing of grades, drainage, right-of-way & layouts of plans of roadways; West; $5,900.

POSITIONS AVAILABLE

D-9758, Jr. Sales Engr's. ME or Ch.E. degrees; will enter a training program before being sent into the field; must have an interest in industrial lubricants & their uses; sal. $365 to start; age 25-30; location, Detroit area.

D-9891, Sales Trainee. ME degree; to contact oil companies, service stations & bulk plants on sales of storage tanks, pumps & allied petro. handling equipment in northern Michigan; sal. $400/mo.; age under 30; location, Michigan.

D-9913, Industrial Lubricants Salesman. Qualified to sell & service industrial oils & greases in the Detroit area; sal. $6-7,000; age open; location, Detroit.

C-9252 (a), Recent Graduates. Degree required; will enter training for positions in either operations or marketing with major petroleum co.; sal. $350-375/mo.

C-2413, Tech. Writer. Mech. background; 3 yrs. exp. in tech. writing of manuals & specs.; know process industry desired; duties, tech. writer on specifications, manuals, standards operating procedures; production reports for chemical company; sal. $6,300-7,200; loc., Texas.

C2543(a), Research Engineer. Grad. Chemist or Che. Eng.; age to 50; duties, research & development on coatings, plastics, resins, solvents, petroleum products; should have ability to carry on project without too much supervision; sal. $5-6,000; loc., Kankakee, Ill.

C-2543(b), Chem. Engr. or Chemist. Grad.; age to 27; 2-4 yrs. exp. in research & development; duties, act as ass't. & sec'y. to research director; some research projects on paint & petroleum; position offers good potential for advancement; good personality, some customer contact work involved; for mfgr. of asphalt products; sal. $5,000 top; location, Kankakee.

C-2653, Field Engr. CE or Geol.; age up to 40; recent graduates or better—one man to know surveying; duties, drilling units or compaction controls on soils; for testing soils company; sal. $4,600-5,400; employer will negotiate fee; travel about 50% of time; car helpful; loc., Hq. Chicago.

ASLE Publications

84 E. Randolph St. **Chicago 1, Illinois**

FUNDAMENTALS OF FRICTION AND LUBRICATION IN ENGINEERING

Proceedings of 1st ASLE National Symposium: Historical Development of Hydrodynamic Lubrication; Remarks on Mixed Film Lubrication; Lubrication Concepts & Engineering Application; Hydrodynamically Lubricated Roll Neck Bearings; Fundamentals of Hydrodynamic Lubrication; Vertical Pivoted Shoe Thrust Bearings; On the Need for a Non-Steady State Theory for Lubrication Hydrodynamics; Lubrication of Gear Teeth, Including the Effect of Elastic Displacement; Physics & Chemistry of Rubbing Solids—Basic Principles; On the Friction & Wear of Graphite & Other Layer-Latticed Solids; The Importance of Wear Fragments During Sliding; Technical Applications of Principles of Solid Sliding Contact. $3.00 per copy to members, $3.50 per copy to non-members.

INTERPRETING SERVICE DAMAGE IN ROLLING TYPE BEARINGS

A manual on ball and roller bearing damage which includes drawings, tables, and 74 photographs for aiding in the classification and identification of the causes of many of the common types of bearing damage. $1.00 per copy.

LUBRICATION ENGINEERING DECENNIAL INDEX

Subject & Author Indexes listing the papers published in **Lubrication Engineering,** Journal of the American Society of Lubrication Engineers, in Volumes 1 thru 10 (1945 thru 1954). 50c per copy.

PETROLEUM-TYPE HYDRAULIC FLUIDS

Second in the series of ASLE monographs, covering Hydraulic Oil Specifications & Service Properties, Viscosity, Viscosity Index, Demulsibility, Oxidation Stability, Lubricating Value, Rust & Corrosion Preventive Qualities. $1.00 per copy.

PHYSICAL PROPERTIES OF LUBRICANTS (Second Edition)

First in the series of ASLE monographs, covering Viscosity, Density & Specific Gravity, Cloud & Pour Points, Flash & Fire Points, Carbon Residue. Neutralization Number & Interfacial Tension, Saponification Number, Emulsification, Specific Heat. $1.00 per copy.

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Why continue to waste press lubrication dollars through lack of Farval?

FARVAL—
Studies in Centralized Lubrication No. 161

ANY pressroom foreman will tell you that lubricating *even one* press by hand is costly. Costly in time, production lost, bearing repairs and lubricant wasted!

On the other hand, hundreds of foremen will tell you that Farval can save all this needless expense—*immediately* upon installation. That's because FARVAL, the Dualine system of centralized lubrication, delivers oil or grease, in exact measure simultaneously to every individual bearing as often as desired and while a machine is operating.

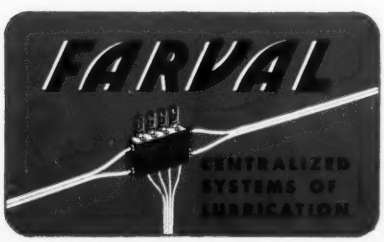
Farval saves $66,000

For example, Whiteway Stamping Company, Euclid, Ohio, first installed one Farval system on a press in 1928. Result? An end to press shutdowns for lubrication! Several hours of expensive oiling labor saved each day! Nine other large presses were *Farvalized.* So well has Farval worked that in 26 years not a single bearing has been lost for lack of proper lubrication. Today, the owner estimates that in the quarter century that Farval has been in operation, he has saved at least $66,000 in oiling labor alone, not to count thousands of hours of production time. Yet, *total* Farval investment was only $1,087 per press!

Free Lubrication Survey

So, why not let us send one of our lubrication engineers to inspect *your* plant equipment? Without obligation, he will present a *confidential* written analysis of what Farval can do for you. The savings will surprise you! The Farval Corporation, 3267 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.



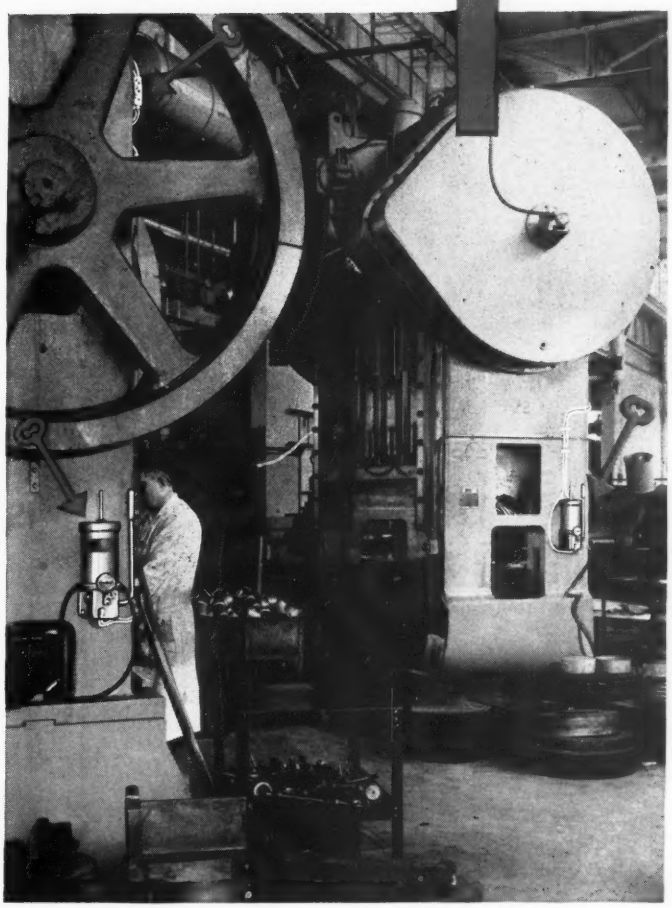


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Photo shows two of the ten presses at Whiteway Stamping Company, with a Farval manual pumping station conveniently installed on each.

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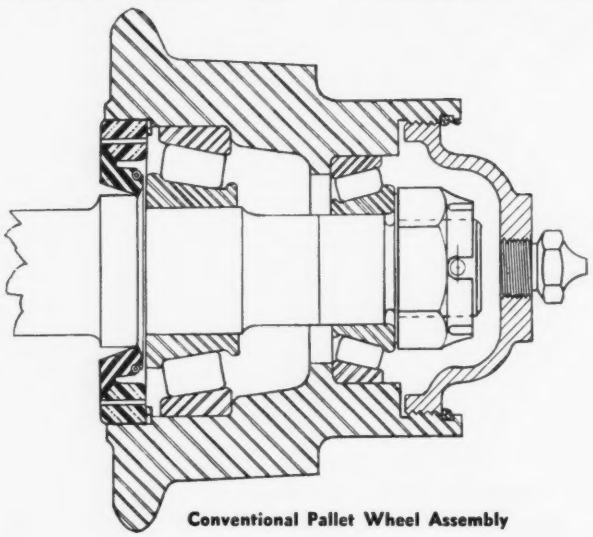
No. 3-497 NON-MELTING LUBRICANT FOR BEARINGS OF PALLET WHEELS



Conventional Pallet Wheel Assembly

LUBRICATION CYCLE FOUR MONTHS INSTEAD OF FOUR DAYS

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